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# Abstracts of the Fifth North American Echinoderm Conference, Melbourne, Florida, 20-25 July 2008

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**ABSTRACTS OF THE FIFTH NORTH AMERICAN  
ECHINODERM CONFERENCE  
MELBOURNE, FLORIDA, 20–25 JULY 2008**

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## FOREWORD

### FIFTH NORTH AMERICAN ECHINODERM CONFERENCE— MELBOURNE, FLORIDA, 20–25 JULY 2008

These abstracts represent research studies presented at the Fifth North American Echinoderm Conference (NAEC) sponsored by the Florida Institute of Technology and the University of Alabama at Birmingham, 20–25 July 2008. The meeting was held on the campus of the Florida Institute of Technology in Melbourne, FL. Those attending the conference were gathered in large part to recognize the outstanding past, present, and future career of John M. Lawrence (see abstract by J. S. Pearse), the quintessential echinoderm biologist. We wish

to thank Carolyn Wood (Assistant Editor) and Monty Graham (Editor) for facilitating publication in *Gulf of Mexico Science*.

#### ORGANIZING COMMITTEE:

RICHARD L. TURNER, *Department of Biological Sciences, Florida Institute of Technology, Co-organizer and sponsor of the 5th NAEC.*

JAMES B. McCLINTOCK, *Department of Biology, University of Alabama at Birmingham, Co-organizer of the 5th NAEC.*



## ABSTRACTS

**Seasonal Variation of Assemblage Fauna to *Ophioplocus januarii* (Echinodermata: Ophiuroidea) in Golfo San José, Patagonia**

L. P. ARRIBAS, P. E. PENCHASZADEH, AND M. I. BROGGER

Mixed substrates comprised of tuff and sand at Golfo San José (Patagonia) are known to harbor a high biodiversity. In the present study, the fauna living with the ophiuroid *Ophioplocus januarii* were analyzed and related to season. Random samples were seasonally collected over 50 square centimeters at subtidal depths in Playa Villarino between December 2005 and August 2007. The fauna was identified and grouped into different taxonomic levels. We observed a dominance of Mollusca (mainly Trochidae and Mytilidae), Polychaeta (mostly Nereidae), and Crustacea (mainly Amphipoda—Lysianassidae, Phoxocephalidae, Leptostraca, and lower abundances of Isopoda and Ostracoda). Differences in abundances of rock-boring species and species associated with soft sand were observed. This can be related to the proportion of hard/soft substrate sampled in each season. The abundances of *O. januarii* were highly variable through the study period. Considering this peculiar environment, with its frequent storms and wide range of tides, it is not possible to ascribe these variations to a natural seasonal condition.

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**Reproduction in Two Species of *Patriella* Living in a Southern New Zealand Fiord**

M. F. BARKER

Unique climatological and hydrographic conditions in Fiordland, southwest New Zealand, produce a near freshwater layer (LSL) on top of fully marine water. The starfish *Patriella regularis* lives within the LSL, while *P. mortenseni* occurs immediately below it in full-salinity seawater. It seems possible that living at low salinities places *P. regularis* under considerable physiological stress with high metabolic costs which affect other metabolic processes such as reproduction. In the study reported here *P. regularis* and *P. mortenseni* were collected over 15 months from an outer and inner site in Doubtful Sound, and gonad and pyloric indices determined. At the peak of the breeding season ripe individuals were spawned, and the eggs and embryos were fertilized in a range of salinities from 15 to 35‰. Reciprocal hybridization of each species was attempted. Both species of starfish have an annual reproductive cycle, with summer spawning from December to February in *P. regularis* and December to March in *P. mortenseni* in 2007. In *P. regularis* gonad and pyloric caeca indices were higher in the inner than outer sound, while in *P. mortenseni* only pyloric caeca indices were higher in the inner sound. In both species more than 80% of eggs were fertilized at salinities greater than 25‰; however, at salinities of 20‰ or less, few eggs were fertilized. *P. regularis* eggs did not fertilize with *P. mortenseni* sperm and only a low percentage of eggs were fertilized in the reciprocal cross.

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**Regeneration Rate in Four Species of Caribbean Ophiuroid (Echinodermata: Ophiuroidea)**

D. L. BEDDICK, JR. AND C. M. POMORY

Ophiuroids are noted for the ability to autotomize and regenerate arms, usually in response to a predation event. The rate of regeneration determines how quickly an individual returns to full functionality. Ophiuroids were collected in shallow water off of Long Key, Florida, and transported to laboratory facilities at the University of West Florida. Arm regeneration rates in *Ophiocoma echinata*, *Ophiocoma wenditi*, *Ophiothrix oerstedii*, and *Ophioderma brevispinium* were determined following removal of either two or four arms by analysis of photographs taken during the regeneration process. Percent regeneration was calculated by dividing the length of regenerated arm by the total length of a whole arm in the same individual. Preliminary data after 126 days of regeneration indicate that rate of regeneration per arm is similar between individuals regenerating two or four arms. Arm regeneration rates were *Ophiocoma echinata* (0.30 mm/d, 29%), *Ophiocoma wenditi* (0.35 mm/d, 35%), *Ophiothrix oerstedii* (0.17 mm/d,

38%), and *Ophioderma brevispinium* (0.2 mm/d, 40%). While regeneration rate per arm remains similar, total amount of regenerated tissue increases with increasing damage which should require a larger energetic investment.

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### **Taxonomic List of the Asteroidea and Echinoidea of the Coast of Oaxaca, Western Mexico**

F. BENÍTEZ-VILLALOBOS, E. CASTILLO-LORENZANO, AND G. S. GONZÁLES-ESPINOSA

A systematic list of the echinoderms (Asteroidea, Echinoidea) off the coast of Oaxaca in Southern Mexican Pacific is presented. The list is based on fieldwork and museum specimens from the Colección Nacional de Equinodermos, Instituto de Ciencias del Mar y Limnología, the Universidad Nacional Autónoma de México, the National Museum of Natural History, and the Smithsonian Institution, Washington, D.C. A total of 27 echinoderm species are presented that represent 23 genera, 17 families and 9 orders. Eleven new records for the state of Oaxaca, Mexico, are included.

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### **Echinoderms Collection of Colombian Museum of Marine Natural History (MHNMC)**

G. H. BORRERO-PÉREZ AND M. BENAVIDES-SERRATO

The echinoderm collections of the Colombian Museum of Marine Natural History (MHNMC) has 2,796 lots of five classes, principally collected from regions of the Colombian Caribbean Sea, with additional representatives from the Colombian Pacific, the United States and Mexico. The first record was obtained in 1981, and by 1999 had reached a total of 214 records. This increase was primarily the result of material deposited in the collections by a variety of INVEMAR projects. The most important project to date is MACROFAUNA, which has dramatically increased the representation of echinoderms from soft bottom habitats of the Caribbean Sea (20–500 m depth). The evolution of the collection coincides with information retrieval organized by the MHNMC-INVEMAR, which in 1999 improved the preservation and management of the collections. This entity has also improved the systematization of information through the Marine Biodiversity Information System (SIBM) available through the INVEMAR web page ([www.invemar.org.com](http://www.invemar.org.com)).

*Department of Ecology and Hydrology, University of Murcia, Campus of Espinardo, 30100 Murcia, Spain; and The Institute of Marine and Coastal Research "José Benito Vives de Andreis" (INVEMAR), Cerro Punta de Betín, AA 1016, Santa Marta, Colombia.*

### **Distribution of Bipinnaria and Pilidium Larvae in Relation to Physical Structure and UV-B Light in the Water Column off Anvers Island, Antarctica**

I. BOSCH, W. B. JAECKLE, AND D. KARENTZ

Feeding larvae of Antarctic bottom invertebrates have proven to be scarce in the plankton and consequently our knowledge of their ecology is limited. We collected bipinnaria larvae assignable to the genus *Odontaster* and several types of pilidium larvae of nemertean worms in quantitative net tows taken during the austral spring and summer 1997–1998 and considered their distribution with respect to the density stratification of the water column and the potential exposure to UV-B ( $\lambda = 308$  nm). The average number of pilidium and bipinnaria larvae in the upper 40 m of the water column was  $0.5 \pm 1.0$  per  $m^3$  and the highest abundance was 2.1 per  $m^3$  in early January when 270 bipinnariae were collected at a depth of 28 m. In October and November, water density ( $\sigma_t$ ) in the upper 40 m was relatively uniform and bipinnariae and pilidiums were collected from 2 m to the maximum depth sampled (20–38 m). Beginning in December and continuing into February, surface melt produced a marked stratification of the upper water column with a major discontinuity layer at 10–15 m, and larvae were relatively rare near the surface. Larvae drifting at a depth of 4 m during periods of ozone depletion in October and November 1997 would potentially experience average maximum UV-B exposures of 80.10 joules/ $m^2$ /hr. Later in spring and summer, under a normal ozone column, average maximum potential exposures were 2.26 joules/ $m^2$ /hr at 14 m, where larvae were abundant. The physiological and ecological consequences of high surface exposures to UV-B during

periods of ozone depletion depend on several factors, including stage of development and residence times of larvae near the surface, and remain largely unknown.

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### Loss of Arm Spines in the Basketstar *Astrophyton muricatum* From the Gulf of Mexico

J. M. BOUCHER AND R. L. TURNER

Some genera of basketstars are characterized by lacking arm spines on basal segments. This character, used in some dichotomous keys, would be reliable if basal arm segments failed to grow spines. But we have found arm spines on basal segments of small *Astrophyton muricatum*, a species previously thought to lack them. For benthic ecologists working in the Gulf of Mexico, there is a potential for confusion of young *A. muricatum* with *Astrocyclus caecilia*, a species that retains basal arm spines throughout life. We examined 72 *A. muricatum* and 14 *A. caecilia* from material collected during the Hourglass cruises in 1965–1967, supplemented with 5 *A. muricatum* from cruises of Project SEAMAP in the 1980s. *A. caecilia* with disc diameters of 15.8–38.8 mm bore arm spines on basal segments before the first fork (branching) of the arms. Specimens of *A. muricatum* with disc diameters of 2.0–9.1 mm also bore arm spines before the first fork; larger specimens progressively lost basal arm spines, bearing them only on arm segments before the second (4.5–20.2 mm), third (18.1–38.0 mm), fourth (17.6–52.9 mm), fifth (35.1–82.4 mm), or sixth forks (59.9–61.5 mm). Examination of arm spines by scanning electron microscopy reveals that basal arm spines have signs of resorption. Basal lateral arm plates that have lost arm spines display reduced specialization for holding spines: the stereom on what should be spine-bearing surfaces is less compact; depressions for receipt of connective tissues and/or muscles and for transmission of nerves are shallow. Evidence indicates loss of arm spines occurs by resorption rather than by breakage or other wear, failure to regenerate lost spines, or histolysis.

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### The Holothurian PEET Project and the Aspidochirotid Working Group: Integrative Taxonomy on a Large Scale

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We are undertaking a major revision of holothurians, focused on the Aspidochirotida, with support from the NSF PEET program, additional funding from our institutions, governments, and other sources. The project includes reviews of nomina, literature, type specimens, field surveys, DNA sequencing, and revisionary taxonomy. For nomina we are upgrading and data basing Smiley and Pawson's (1990's) manuscript on holothurian names. This is resulting in a comprehensive database of the >2,500 available holothurian nomina, with relevant information checked, verified, and captured. Scans of original descriptions of aspidochirotid nomina are being posted on the PEET-cuke web site (<http://67.98.162.85/marinelab/peetcukes/>), together with ca. 6,200 references dealing with holothurians. Major repositories with holothurian type material are being surveyed, aspidochirotid type material identified, and fresh ossicle preparations made from relevant tissues of these. Collections in Hamburg, Berlin, Moscow, Paris, London, and our home institutions have now been studied. Many type specimens once considered lost, especially from Semper's work, have been rediscovered. Field surveys have focused primarily on shallow, tropical waters and to date have resulted in large, new collections from the Comoros, Mascarene, Philippine, Vanuatu, Fiji, Mariana, Caroline, Marshall, Cook, Society, Line, and Hawaiian Islands, Australia, Panama, Mexico, Mediterranean Basin, Florida, and Washington. Several new species as well as fresh tissue samples from many species were obtained on these trips. DNA has been extracted from >1,600 specimens and sequenced from >1,100 to date, representing >350 species, focused on aspidochirotids, but covering other available, appropriately preserved holothurian species. Sequence data, field appearance (including photodocumentation for recently collected material), ossicle complements, and internal anatomy are being integrated to redefine taxa, with many species complex challenges getting sorted out. Student theses and projects are focused on partial to comprehensive revisions of: *Stichopus*, *Actinopyga*, *Bohadschia*, *Holothuria (Thymiosycia)*, *Holothuria (Selenkothuria)*, *Holothuria (Halodeima)*, and *Synapta*, with other projects in the works.

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### Alteration of Quartz Sand-Sized Sediments by *Mellita tenuis* (Echinodermata: Echinoidea)

R. C. CHALLENGER, M. F. MILLER, AND D. J. FURBISH

Earlier studies have proposed the intriguing hypothesis that sand dollars break down sand-sized sediments composed of quartz. If true, sand dollars exert a significantly greater control on substrate textures in nearshore environments than previously thought. Differences in grain size distributions between the substrate and the digestive system of the sand dollar *Mellita tenuis* exist but provide no evidence that sand dollars break down sand-sized quartz particles. Grains may abrade against one another, causing breakage, but this is rare. The lack of freshly broken textures observed using scanning electron microscopy (SEM) of ingested grains coupled with ambiguity in the degree of angularity of ingested versus exterior grains supports the conclusion that sand dollars are not breaking down quartz grains on a large scale. Therefore sand dollars are not significantly altering the texture of nearshore marine sands. A new hypothesis, that long-term entrainment of smaller grains within the gut may be due to the presence of a diverticulum, is presented to account for the apparent accumulation of finer grains within the gut.

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### Sequence Variation in the Hemoglobin Gene of *Ophiactis* spp.

A. B. CHRISTENSEN AND E. F. CHRISTENSEN

Analysis of a fragment of the COI gene suggests that populations of the brittle star *Ophiactis simplex* from California and Texas share a recent evolutionary history and may be in the process of speciation (Christensen et al 2008). As both groups produce the respiratory pigment hemoglobin and hemoglobins from even closely related species typically share less than 50% homology, an investigation into sequence similarity was performed. cDNA was isolated from the Texas ophiactid and PCR amplified using primers specific to *Hemiphysalis elongata* hemoglobin. A total of 1,111 nucleotides were sequenced: a) 52 nucleotides from the 5' noncoding region, b) 579 nucleotides from the noncoding 3' region, and c) 480 nucleotides from the coding region (including start and stop codons). The coding region translates into a protein of 158 amino acids long. Internal primers were generated from this sequence and used to PCR amplify genomic DNA and search for introns. The gene for hemoglobin A has three introns, two that are typical of all vertebrate and many invertebrate hemoglobins and a third that is reported for some echinoderm hemoglobins. The protein coding sequence and sequence of intron 2 is identical from Texas individuals and California *O. simplex*; intron 2 is 314 bases long. These similarities lend evidence that the populations share a common origin and are possibly the same species. However, we did find three different versions of intron 1. The most common version, A, had 800 bases and occurred in both Texas and California populations. The other two versions, B (851 bases) found in California and C (845 bases) found in Texas, both shared the same 54 base insert and are more similar to one another than they are to A. Intron 3 occurs between the codons for amino acids 8 and 9 and is over 1,100 bases long.

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### A Comparison of Behavioral Separation in Two Species of *Luidia* (Echinodermata: Asteroidea)

P. CORIES AND C. M. POMORY

*Luidia* is a genus of sand-dwelling asteroid in the Gulf of Mexico and Caribbean Sea. *Luidia clathrata* is a common five-armed species in this region. Recently (Hopkins, in press) a new species has been described, *Luidia lawencei*,

based on specimens previously identified as *L. clathrata*. Anecdotal observation suggests *L. clathrata* is more common in shallow bays with fine sediment and fluctuating, lower salinity conditions; while *L. lawrencei* is found in deeper off-shore waters with coarser sediment and ocean salinity. The present on-going study is investigating various aspects of the biology of the two species including: sediment selection, salinity tolerance, and genetic separation. Statistical results using a goodness-of-fit frequency test suggest that *L. clathrata* is selective towards finer sediment ( $P < 0.05$ ) while *L. lawrencei* shows no particular preference ( $P > 0.05$ ). Responses to acute salinity changes demonstrate a definite attenuation of the organism's activity level. Both species slow down noticeably when transferred from 35 ppt to lower salinities. Other factors may be more important in separating the two species in the natural environment.

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## Community Structure of Echinoderms Associated With Coral Reefs in Bahias de Huatulco, Western Mexico

J. P. DÍAZ-MARTÍNEZ AND F. BENÍTEZ-VILLALOBOS

The phylum Echinodermata is one of the most conspicuous and abundant groups of invertebrates in coral reef communities. The members of this phylum are included in different trophic groups, such as detritivores, filter-feeders, grazers, scavengers and predators. As such, they play important roles in community structure. The objective of this study was to examine and compare the structure of echinoderm communities from six localities in Bahias de Huatulco Oax, Mexico. Data obtained from April 1994 to April 1995 was used in analyses. For community characterization, Shannon diversity index ( $H'$ ), Simpson dominance index ( $I$ ) and Pielou evenness index ( $J'$ ) were employed. In addition, an ordination analysis (MDS) and an ANOSIM test (analysis of similarities), both based on Bray-Curtis similarities, were conducted, to identify groups of localities with similar faunistic compositions. Species richness and diversity were higher in La Mina in contrast to Puerto Angel where species richness and diversity had the lowest values. The analyses detected one biogeographic group consisting of Chachacual, Puerto Angel and La Mina and a second biogeographic group consisting of La Casa Mixteca and Puerto Angelito. La Entrega was the only locality that did not integrate into a group. The ANOSIM test indicated that there were significant differences between localities. The groups of localities that had the largest average of dissimilarity were La Mina-Puerto Angel (68%), La Mina-La Entrega (72%), Puerto Angel-La Entrega (80%) and La Entrega-Casa Mixteca (71%). The brittlestar *Ophiactis savignyi* and the sea cucumber *Holothuria impatiens* were the most important species regarding their contribution to the measured variability.

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## Multixenobiotics Resistance in Coelomocytes of Two Echinoderm Species of the St-Lawrence Estuary

E. DOUSSANTOUSSE, L. BEAULIEU, L.-C. RAINVILLE, C. BELZILE, AND É. PELLETTIER

Multixenobiotics resistance (MXR) is a molecular process similar to multidrug resistance (MDR) first observed in tumour cell lines resistant to anti-cancer drugs. This mechanism is associated to an active export of molecules by trans-membrane proteins. Those proteins protect cells against aggressive endogenous or exogenous molecules. Most studies have been made on the P-glycoprotein (P-gp) and the multi-resistance proteins family (mrp), specially the human mrp1 homologue. MXR proteins are known to be conserved through evolution, but very few studies have been made in echinoderms. Our objective was to investigate the presence of proteins like P-gp and/or mrp in coelomocytes of sea urchin *Strongylocentrotus droebachiensis* and sea star *Leptasterias polaris*. We first developed an indirect determination of the protein activities by flow cytometry. Cells have been exposed to fluorescent substrates (1  $\mu$ M rhodamine or 0.5  $\mu$ M calcein-am) with or without inhibitors (50  $\mu$ M verapamil, 5  $\mu$ M cyclosporine-A and 5  $\mu$ M MK571). We observed an accumulation of rhodamine in coelomocytes of *S. droebachiensis* with all inhibitors and in coelomocytes of *L. polaris* and vibratile cells of *S. droebachiensis* only when cyclosporine-A was used. Also, we observed a diminution of calcein accumulation in coelomocytes of *L. polaris* and vibratile cells of *S. droebachiensis*. In a second step, a direct measurement was applied by using western blot with antibodies against conserved sections of proteins (P-gp C219 and mrp C9). Both P-gp and mrp seemed to be present but could not be discriminated because of the lack of specificity of the C9 antibody. Mass spectrometry did not allow the positive

identification of P-gp or mdr-like proteins, but a major vault protein, another MDR protein, was identified. In conclusion, MXR activity in coelomocytes of *S. droebachiensis* and *L. polaris* was clearly demonstrated but proteins responsible for this activity might not be of P-gp or mdr type.

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### Reassessing Heliometrinids (Feather Stars) Using Congruent Evidence From Multivariate Analysis and Discrete Characters

M. P. ELEAUME AND N. AMEZIANE

Comatulid systematics is partly based upon such characters as "relative length" or "relative proportion" of morphological features. This approach may be seen as a subjective way to describe differences between species. Alternatively, "relative proportions" when based on comparable measurements may be understood as a proxy for shape analysis. As a consequence, shape analysis methods may be applied to this type of features and differences in shape (as opposed to differences in size alone) may help evidence differences between species. To test this idea, 763 specimens and 16 variables have been measured representing five genera, *Anthometra* (1 species), *Florometra* (5 species), *Heliometra* (1 species), *Promachocrinus* (1 species) and *Solanometra* (1 species), within the comatulid subfamily Heliometrinae. Using multivariate analysis after size normalization (log-shape ratio), PCA (for dimension reduction) LDA (for supervised classification) and Mclust (unsupervised classification), original taxa delineation are examined. Discrete morphological features (calyx plate structure) are used to provide convergent evidence. As a consequence, *Florometra mawsoni* is transferred to the genus *Solanometra*.

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### Evaluating Nutrient Requirements in Newly Metamorphosed Juvenile *Lytechinus variegatus* (Echinodermata: Echinoidea)

J. E. ETLING, M. L. POWELL, A. L. LAWRENCE, AND S. A. WATTS

Sea urchins are excellent biomedical and toxicological models, as well as a popular food among many people. However, sea urchin populations are being decimated by overfishing. Due to this high demand, there is an increasing need to develop methods for inland rearing of sea urchins from the larval to the adult stage. Sea urchin larvae transition from free swimming larvae feeding on unicellular algae in the water column to a benthic environment. Little is known about juvenile nutritional requirements at this early developmental stage. Feeding in newly metamorphosed juveniles was examined in settled sibling larvae collected from a single male and female spawn and placed in duplicate 8-L aquaria. Newly metamorphosed urchins were placed in one of four treatments: biofilms of the live diatom *Amphora helenensis*, *A. helenensis* plus diatomaceous earth, *A. helenensis* with a diatom substitute (Reed Mariculture Inc.), and the diatom substitute alone. Individual growth was highly variable within all groups, with a range in diameter from 0.4 to 3.0 mm. Survival was comparable among the first three treatment groups, however, no individuals survived when fed diatom substitute alone. Supported in part by the Mississippi-Alabama Sea Grant Consortium.

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### Annual Cycle of the Gut of the Variegated Sea Urchin *Lytechinus variegatus* From the Northern Gulf of Mexico

V. K. GIBBS, A. W. CUNNINGHAM, AND S. A. WATTS

Numerous studies have reported an annual cycle of the sea urchin gonad; however, very few have investigated an annual cycle of the gut. In this study, *Lytechinus variegatus* (n = 30, ca. 45 mm diameter) were collected every 4 to 6

wk from April 2001 to September 2003 at Eagle Harbor in St. Joseph Bay, Florida, USA. Sea urchins were then transported to the University of Alabama at Birmingham for measurement and dissection. Dry weight indices for the gut and gonad were determined by  $[\text{dry weight of the organ (g)}/\text{total dry weight of the individual (g)}] \times 100\%$ . Over the 2.5 yr sampling period, the gut indices ranged from 0.72% to 1.80% and 0.79% to 2.24% for males and females, respectively. For males and females, gut indices reached a maximum in late winter (February 2003) or in early spring (March 2002) followed by a decrease to a minimum in mid-summer (July 2003) or in early fall (September 2002). A second peak was reached in late fall (October for females and November for males in 2001; October for males and November for females in 2002) followed by a decrease to a low in early to mid-winter (December 2002 for males and January 2002 for males and females). Maximums in gut indices for males and females directly preceded maximums in gonad indices whereas, in early fall, minimums for gut indices coincided with minimums for gonad indices in males and females. These data support the role of the gut as a short-term nutrient storage organ, the size of which is dependent in part on gonad size and maturity as well as seawater temperature.

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### **Settlement Patterns of the Echinoid *Paracentrotus lividus* (Lamarck, 1816) in the Island of Tenerife, Canary Islands, Eastern Atlantic**

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The planktonic period of *Paracentrotus lividus* is estimated to span 1 month. During this period, the larva will live in the water column as a planktotroph until it reaches a competent stage to settle and metamorphose. Settlement of this species was followed from December 2003 to May 2006 using larval collectors in two sites on Tenerife Island. Sampling was performed monthly during the studied period with a gap between June and August 2005. The settlement period was the same for the studied years and was found to occur between January and March. In the studied annual patterns, a single settlement event was observed, with higher settlement rates registered for the year 2004, although significant differences were not found between years. Settlement peaks were related to chlorophyll-*a* concentrations, as an estimation of the amount of phytoplankton, sea surface temperature, and productivity. We conclude that the annual settlement peak of *Paracentrotus lividus* is coupled with the highest values of chlorophyll *a* and the lowest sea surface temperatures in this subtropical area. These results seem to be related to the fact that *Paracentrotus lividus* is a typical temperate species, and its larvae develop and settlement occurs when high phytoplankton abundance is found in the water column.

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### **Reproductive Cycle of the Echinoid *Paracentrotus lividus* (Lamarck, 1816) at Its Southern Population Limit (Canary Islands, Eastern Atlantic)**

D. GIRARD, A. HERRERO, J. MORA, J. C. HERNÁNDEZ, A. BRITO, N. GONZÁLEZ, AND J. L. CATOIRA

The reproductive biology of the echinoid *Paracentrotus lividus* (Lamarck, 1816) is considered of high interest due to the value of its gonads which are appreciated as seafood, being this species is intensely harvested in many places. This echinoid is distributed throughout the Mediterranean and north-eastern Atlantic (from the British Isles to Canary Islands). The purpose of this research is to deepen the knowledge of the reproductive cycle at its southern geographical limit, where temperatures vary from 18°C in winter to 25°C in late summer, which would modify its reproductive strategy. Sea urchins were collected monthly at two sites in the Island of Tenerife (28°N, 16°S) and two in the Island of Gran Canaria (27°N, 15°S) from April 2006 to March 2007. Gonad index (GI) based in fresh weight and gonad histology were used to determine periods of maturity. Results show a high variability in GIs between sites. The histological approach points to a rapid gametogenesis, having several spawnings per year. This contrasts with the results obtained for the same species at higher latitudes (northern Brittany, France; west coast of Ireland or north-eastern Spain), where one or two maturation periods occur per year. We predict that this temperate species has the ability to extend its period of maturity and to spawn multiple times during the year due to warmer water temperatures, regardless of other environmental variables.

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### Further Description of Hybridization Between the Seastars *Asterias rubens* and *A. forbesi* Using Nuclear Markers

F. M. HARPER AND J. MESKO

Recolonization of the northwest Atlantic following the Last Glacial Maximum has led to secondary contact of numerous rocky intertidal invertebrates, including two sibling species of seastars. Following expansion out of their respective refugia along the coasts of the southeastern United States and Europe, *Asterias forbesi* and *A. rubens* have formed a secondary contact zone in the Gulf of Maine and the east coast of Nova Scotia. Previously, we used morphological and mitochondrial DNA (mtDNA) analyses of allopatric and sympatric *Asterias* populations to investigate the possibility of hybridization. While an extensive morphological analysis did not quantitatively support the existence of a distinct group of intermediate phenotypes, three individuals were identified with the phenotype of *A. forbesi* and the mtDNA haplotype (putative control region) characteristic of *A. rubens*. Here we further describe the extent of hybridization between these species using intron regions for two nuclear protein-coding genes (ATP synthase, beta subunit and elongation factor-1, alpha subunit). Phylogenetic analyses of sequences from clones amplified from ATPS beta-introns 5 and 7 yielded very low sequence divergence and no parsimony-informative sites; the two species could not be distinguished using these introns. Preliminary results of cloning and sequencing intron 4 of Ef-1 alpha for both species are more promising: 24 of 609 bp are parsimony-informative sites. Analyses using biparentally-inherited nuclear DNA are needed to better estimate the frequency of hybridization and to test the hypothesis of asymmetric hybridization and introgression in these species.

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### The Contrariwise Life History of a Remarkable Copepod That Infects Brittle Stars

G. HENDLER AND M. DOJIRI

The extraordinary parasitic metanauplius larva of *Caribeopsyllus amphiodiae* is sexually dimorphic, with conspicuous gonads and elaborate lens-bearing eyes. Their free-living, semelparous, non-feeding adults live only two weeks. However, the parasites grow for up to five months within the stomach of burrowing ophiuroids (*Amphiodia urtica*) that live in Santa Monica Bay, California. The species' contrariwise life history pattern, with a larval period approximately ten times longer than the adult life span, is antithetical to that of other copepods but not for animals with non-feeding adults of both sexes. We attribute the dominance of the larval phase in the species' protean life cycle to the greater potential for survival and growth of the parasitic stages than of the free-living, post-metamorphic stages, and we provide an explanation for the absence of non-feeding adults in echinoderms and other major groups of marine invertebrates.

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### First Late Pleistocene Regular Urchin Reported From Florida With Notes on Morphological Variation Among Geographically Separate Modern Populations

J. C. HERRERA, R. W. PORTELL, AND G. H. MEANS

Ten complete tests and numerous radioles of the regular urchin *Arbacia punctulata* were collected from middle to late Pleistocene deposits (Anastasia Formation?) at Dickerson Pits near Indrio in St. Lucie County, Florida. This is the first record of a regular urchin reported from middle to late Pleistocene sediments in Florida. It is only the second fossil record of the extant *A. punctulata*. The one previous report, erroneously identified as *Anapesus carolinus* Troschel by F. S. Holmes (1860), was derived from deposits at Simmons' Bluff, South Carolina. *Arbacia punctulata* is a common littoral echinoid in Florida waters. It inhabits hard bottom or rubble areas from Cape Cod through the Bahamas to Cuba and the Yucatan, in the Gulf of Mexico from Florida to French Guiana, and in the



Lesser Antilles as far north as Barbados. Its depth range has been reported to be from 0 to 225 m. It is generally found in waters less than 50 m in depth. In Florida, *A. punctulata* is usually found more offshore in the Gulf and may be found closer inshore in the Atlantic. This difference is probably due to a preference for hard substrate, which is generally lacking from inshore areas of the Gulf. It is also possible that salinity fluctuations of inshore waters contribute to a more offshore distribution in the Gulf. In *A. punctulata*, many features of test morphology vary geographically. Those features which vary by population geographic location include: number of tubercles in each interambulacral row at the ambitus, width of interambulacral plates as a percentage of test diameter, extent of the aboral naked area, and texture and margin shapes of interambulacral plates. Though there is much geographic variability in test morphology among modern specimens, our Pleistocene specimens and photographs of the Simmons' Bluff test closely resemble modern specimens from the Atlantic Ocean off Ft. Pierce, Florida.

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## Energy Budgets of Four Congeneric Species of Sea Urchins (*Echinometra*) Fed a Prepared Diet

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Energy budgets for four closely related species of sea urchins, *Echinometra* sp. A (Ea), *E. mathaei* (Em), *E. sp. C* (Ec), and *E. oblonga* (Eo), were examined in the laboratory by feeding sea urchins an ad libitum diet prepared from turf algae and agar over a three month period. The energy intake by Ea was significantly greater than that in the other three species. Although absorption efficiency of energy was significantly lower in Ea than in the other three species, the amount of energy absorbed from the diet was similar among the four species. The energy loss in feces was 58.9% of the energy ingested for Ea, and 48.8–50.8% for the other three species. The percentage of energy intake expended in respiration and ammonia excretion was similar for all four species, ranging from 6.0–7.2% and 0.3–0.5%, respectively. The energy loss in secretion, calculated by subtraction, was 32.2% of the energy intake for Ea, and ranged from 41.2–42.3% for the other three species. The energy deposited as somatic and gonad growth was 2.0% and 0.6% of the energy intake, respectively, for Ea and 0.9–1.1% and 0.1–0.2%, respectively, for the other three species. In summary, although all four species channeled most of the absorbed energy into maintenance (i.e., respiration, ammonia excretion, and secretion), Ea allocated a significantly larger proportion and amount of energy to somatic and gonadal growth than the other three species. The distinct interspecific differences in somatic and gonadal growth may be indicative of different life-history strategies between Ea and the other three species.

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## Fencing Behavior in the Antarctic Keystone Sea Star *Odontaster validus*

C. P. HO, J. B. McCLINTOCK, C. D. AMSLER, R. A. ANGUS, AND B. J. BAKER

The circumpolar sea star *Odontaster validus* is ubiquitous in shallow Antarctic seas where it plays a key role in the ecology of benthic communities. A number of studies have investigated aspects of its ecology, reproduction and nutrition. However, little is known about its behaviors. In a recent study we investigated its interactions with several sympatric species of sea stars. The present study extends this analysis to intraspecific behavioral interactions. A prey item, the Antarctic sea urchin *Sterechinus neumayeri* cracked into two halves, was introduced into a large circular sea water tank in the presence of a tightly clumped group of 32 *O. validus* ranging in body size ( $R = 25\text{--}53$  mm). Using time lapse video analysis we followed the movements of sea stars relative to the prey, the sizes of the sea stars that first located prey, whether sea stars interacted with one another in the vicinity of prey, and if so, the nature of this interaction. These observations were made over a 48 h time period and done in triplicate. Movement patterns indicated that *O. validus* does not display distance chemoreception to locate prey, but more likely relies on contact chemoreception. A total of 15 arm-fencing bouts occurred over the course of our study, all within the near vicinity of the prey. "Fencing" consisted of raising of the arms with repeated pushing against another individual's raised arms. These bouts typically ended with one individual moving away, while the "victor" moved on to the prey. When bouts occurred between different sizes of sea stars, the largest individuals ( $R = 45\text{--}53$  mm) always won (remained near prey or moved on to prey). These complex social interactions have important implications in understanding the role of this keystone species in Antarctic benthic communities. Supported by OPP NSF grant 0442769 to JBM and CDA.

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### Starfish Arm Stumps: Wound Closure Patterns and Regeneration Models

F. H. C. HOTCHKISS

Analysis of arm stumps that failed to regenerate an arm tip indicates that positional information in the starfish arm has bilateral symmetry. Clear evidence in these specimens of (abnormal) symmetrical wound closure by inward folding of both sides of the arms (like closing a book) supports this conclusion. In contrast, normal wound closure by downward folding of the aboral surface (like closing a roll-top desk) is followed by arm tip regeneration. It is proposed that the locus of arm tip regeneration works as a signaling center that induces intercalary distal regeneration (the distalization and intercalation model of Agata et al. 2007). It is further proposed that intercalary gap-filling growth is the normal growth mechanism of the arm tip. According to this idea, the positional gap between the terminal plate and the last-formed section of arm is never bridged, and growth is indeterminate. Distalization and intercalary gap-filling behind the terminal plate may help to explain the origins of novel plate series (such as ophiurid under arm plates and stenurid sublateral plates) without the necessity of ancestral primordia for such series. Likewise loss of plate series can have the same suddenness and explanation (one row of marginal plates instead of two). Once the organism possesses this signaling mechanism, then it would seem to be not too difficult for mutations to cause it to show up in more places than just behind the terminal plate. Thus plate series that intercalate anywhere might have this type of origin (such as asteroid actinal intermediate plates, intermarginal plates, dorsolateral plates, etc.). Mosaic evolution and recurrent appearance/loss of intercalary plates within and between echinoderm lineages are expected under this proposal.

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### Coelomogenesis and Nutrition of Clonally Produced Asteroid Larvae

W. B. JAECKLE AND I. BOSCH

Asexual reproduction by planktotrophic larvae of asteroids is an unusual life history strategy exhibited by several species in the families Luididae, Oreasteridae, Ophidiasteridae, and Asteroiidae. Larvae of the former three families reproduce asexually in the field, while the asteroiid *Pisaster ochraceus* has produced clones when larvae are reared in the laboratory. Our knowledge of the processes involved in larval cloning and the biology of the developing clone is fragmentary in nature. We used light, electron, and scanning laser confocal microscopy to study clones that develop through paratomy of the posterolateral larval arms. The archenteron forms by a modified form of gastrulation that is mediated by large numbers of mesenchyme cells as reported by Bosch et al. (1989). Coelomogenesis is by enterocoely through outpockets of the clonal archenteron. The results of experiments designed to trace the movement of the protein ferritin in larval tissue revealed that clonal embryos may be nutritionally dependent on the primary larva. Organic materials assimilated by the primary larva are translocated through the blastocoelic compartment and accumulate differentially in actively clonal arms suggesting a stronger sink for blastocoelic nutrients compared to nonclonal arms. At the early bipinnaria stage clones are capable of feeding through the capture of particles and assimilation of dissolved proteins from water. By the time they separate from the primary larva the clones are morphologically indistinct from sexually produced bipinnariae of equivalent size.

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### Friend or Foe: Predation and Competition of Small Macrofauna With Juvenile Sea Urchins *Strongylocentrotus droebachiensis* and Sea Stars *Asterias* spp.

L. B. JENNINGS AND H. L. HUNT

Early post-settlement mortality has a large impact on many benthic invertebrates. In our previous research, both the green sea urchin *Strongylocentrotus droebachiensis* and the sea stars *Asterias* spp. had high mortality between the time of settlement and recruitment a year later in Passamaquoddy Bay, Bay of Fundy, Canada. A field caging

experiment was conducted in 2007 to examine if predation by and/or competition with small macrofauna are significant sources of mortality during the first months of benthic life. In two separate experiments, sea urchins or sea stars were placed in small cages with 750- $\mu$ m mesh. Cobbles free of organisms were placed in half the cages, while the cobbles in the rest of the cages contained the natural suite of small macrofauna. Kelp was added to half of the sea urchin cages, resulting in four treatments for sea urchins. Sea stars experienced two treatments with no added food. After 1 or 2 months (stars and urchins respectively) the cages were removed and the numbers of marked echinoderms remaining were counted. Sea urchins survived better in cages where the other organisms were removed, indicating predation likely has an important role. There was also a trend in the cages with the suite that added kelp tended to increase survival, indicating that interspecific or intergenerational competition may be important. This trend of better survival with added kelp was not seen in cages where the suite of other organisms was absent. Sea stars showed the opposite trend. A greater proportion of sea stars survived in cages where the other organisms were present, presumably due to them being a food source, indicating that competition for food and hence starvation is likely important for recent settlers of this taxa. These results indicate that early post-settlement mortality has multiple causes which differ between these species.

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### **Sibling Sea Urchin Species of the Genus *Echinothrix* in Hawai'i: Morphology, Genetics, and Ecology**

H. JESSOP AND H. A. LESSIOS

The sea urchin genus *Echinothrix* of the Indo-Pacific is comprised of two very similar co-existing species which can sometimes be difficult to distinguish, although they do possess some morphological differences. In addition, a number of recently documented spine and test differences between *E. calamaris* color morphs suggest that this species may be polytypic. The existence of possible cryptic sibling species in this genus has also been suggested by an independent analysis of mitochondrial DNA clades. To begin to unify phenotype with genotype, we have investigated *Echinothrix* morphology, genetics, and ecological partitioning in Hawai'i. Our data support the hypothesis that sets of physical characteristics distinguishing *Echinothrix* species are congruent with reciprocally monophyletic mitochondrial ATPase8/6 clades. However, we find no support for additional morphological or genetic divergence beyond the two currently recognized species, in Hawai'i. Color morphs of *E. calamaris* from Hawai'i possess indistinguishable mitochondrial haplotypes, and so are not the result of divergent evolutionary histories. We also present field survey data of interspecific differences in *Echinothrix* habitat preferences on Hawaiian coral reefs. Our synthesis of morphological, genetic, and ecological investigations provides improved recognition and definition of *Echinothrix* diversity.

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### **Histometric Analysis of Nutritive and Gametic Tissue in *Lytechinus variegatus***

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The role, if any, of selenium in sea urchin physiology is not known. Isocaloric semi-purified feeds were supplemented with one of three levels of dietary selenium (0.6, 1.1, and 2.4 mg Se/kg feed). Small sea urchins (average 15 g wet weight, 30 mm diameter) were held individually in semi-recirculated systems and fed ad libitum for 12 weeks. For each sea urchin, a single gonad was removed and prepared for histometric analysis. Sea urchin gonad tissue samples from each sea urchin were preserved in Davidson's media and transferred to 70% ethanol after 24 hours. Samples were sectioned for histology and stained, using hematoxylin and eosin as the primary stain. Image analysis software (ImageTool 3.0, The University of Texas Health Science Center in San Antonio) was used to evaluate sections. Significant variation was observed within and among dietary treatments. Female sea urchins fed the 1.1 ppm selenium feed had a significantly higher percentage of area associated with the germinal epithelium than females fed the 0.6 ppm selenium feed ( $p = 0.03$ ). Female sea urchins fed the 0.6 ppm and the 2.4 ppm selenium feeds had significantly higher oocyte long diameters than female sea urchins fed the 1.1 ppm selenium feed ( $p = 0.02$ ,  $p = 0.003$ ). Female sea urchins fed the 1.1 ppm selenium feed had significantly higher reproductive potential, defined by the number of gametes in the acinus multiplied by the gonad wet weight, than those fed the 2.4 ppm selenium feed ( $p = 0.03$ ). Female sea urchins fed the 2.4 ppm selenium feed had a significantly higher percentage of acinus area as nutritive phagocytes than those fed the 1.1 ppm selenium feed ( $p = 0.02$ ). Nutritive cell and gamete populations in male sea urchins did not vary with dietary selenium under the

conditions of this study. These data indicate the importance of dietary selenium in altering the nutritive and gametic tissues in the sea urchin. This research was funded in part by the Mississippi-Alabama Sea Grant Consortium.

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### ***Acanthaster planci* Distribution and Predation at Pearl and Hermes Atoll**

E. E. KEENAN, R. E. BRAINARD, AND L. V. BASCH

*Acanthaster planci*, Crown-of-Thorns sea stars, are a natural component of Pacific reef ecosystems which are prone to population outbreaks with significant ecosystem effects at some locations. The results obtained from extensive studies at other geographic areas do not necessarily apply to the Hawaiian Archipelago, in particular to the remote Northwestern Hawaiian Islands (NWHI). The reefs of these islands are composed of unique assemblages of organisms due to their geographic and oceanographic isolation and their distinction as occurring near the northernmost edge of coral reef distribution. This research is directed at an initial understanding of the effects that a corallivore like *A. planci* may have on the NWHI ecosystem. During the summer of 2003, data on the abundance and distribution of *A. planci* within the lagoon at Pearl and Hermes Atoll were collected by the NOAA Fisheries-led multi-agency marine debris removal team. Data were collected using manta tows and included depth, whether *A. planci* were eating or not when observed, and the number and genus of coral heads that were preyed upon in the area. There were over 500 sightings documented and mapped over the duration of the survey. *Acanthaster planci* was commonly found to be preying on *Porites* spp. which have been shown to be less favored than *Pocillopora* spp. or *Montipora* spp. in previous research. Management applications of these data may include using estimates of *A. planci* abundance, coral cover, predation rate, and coral growth rates to predict the potential impact of *A. planci* on reefs in the NWHI.

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### **Sea Cucumbers in Western Literature From Antiquity to Linnæus and Beyond**

A. M. KERR

The starting point of modern zoological nomenclature is ostensibly the tenth edition of Linnæus' *Systema Naturæ* published in 1758. However, terms likely referable to our totem beasts, the holothuroids, occur sporadically in Western literature as far back as Classical times. In this presentation, I trace holothuroid nomina from a dubious first mention circa 450 B.C. by the comic poet Epicharmus to the lively series of emendations in disposition within the twelve editions of *Systema* that included as congeners hydrozoans, tunicates and a priapulid worm. From medieval times through the Enlightenment, holothuroids were known by colloquial and occasionally quite descriptive names. The etymology of the term holothuroid itself is likewise uncertain. Indeed, what Aristotle referred to as *ὄλοθορον* was doubtless not a sea cucumber at all, but the name, nevertheless, came to designate the class, probably via a mis-ascription in 1554 by Rondelet in his well illustrated *Libri de piscibus marinis*. Nevertheless, the name *Holothuria*, and thus Holothuroidea, was not certain until the ICZN stepped in and finally settled the 2,500-year disagreement over its proper ascription in 1924.

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### **Ciliated Funnels in the Sea Cucumber *Synaptula hydriformis***

H. A. KOVALAK, M. N. SCHRANDE, AND R. L. TURNER

Ciliated funnels are coelomic organs that occur only in apodous holothuroids. Funnels have received little attention aside from their potential use in holothuroid systematics. Their function is not clear, but some observations strongly indicate a role in ridding the body of foreign material. The purpose of the present study was to describe the morphology of the ciliated funnels in *Synaptula hydriformis*. Specimens were collected from Lake Surprise, Key Largo, Florida, in January 2007. Specimens were fixed in glutaraldehyde and critical-point dried

before or after dissection for examination by scanning electron microscopy. The ciliated funnels were located on both sides of each of the three mesenteries. The linear density was  $84.2 \text{ funnels mm}^{-1}$ . Funnels of *S. hydriformis* were similar to those of *Leptosynapta inhaerens* (Jans & Jangoux, 1989) in a several ways: (1) the funnels occurred either singly or grouped, (2) they were oriented in all directions, and (3) a cluster of coelomocytes was usually associated with each funnel. Funnels of *S. hydriformis* differed in the following ways: (1) the funnels were highly ciliated with long cilia, (2) the number of microvilli at the base of each cilium varied from 8 to 12, (3) the peduncle varied from funnel to funnel in length and thickness, (4) the corolla was only slightly or not at all involute, and (5) the funnels lacked basal cilia. A possible developing funnel was found in a pentactula, but more material must be examined to study ontogeny of the organ. Future studies are needed to determine if the ciliated funnels are able to perform excretory functions and to use transmission electron microscopy to examine the internal structure of the funnels.

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### Amount of Arm Loss and Rate of Arm Regeneration by *Luidia clathrata* (Echinodermata: Asteroidea)

J. M. LAWRENCE AND C. M. POMORY

Thomas Hunt Morgan (1901) stated "The rate of regeneration is considered to be directly related to the amount of body lost". He based this on an observation by his student, Elizabeth King (1898). She gave a figure of *Asterias vulgaris* showing the difference in regenerating arm length according to position of arm amputation. This relationship is known as Morgan's law (Moment 1953). Similar general descriptions of amount of an arm lost and regeneration rate in starfish and brittlestars have been reported (Morgulis 1909, Zirpolo 1926, Edmonson 1935). We amputated three contiguous arms of eight *Luidia clathrata*. The mean length (from the disc) of intact arms was  $57 \pm 7$  mm; the mean lengths of the arm stumps were  $12 \pm 2$  (proximal),  $24 \pm 4$  (medial) and  $41 \pm 3$  (distal) mm. The starfish were maintained without food in one aquarium. Buds appeared on all amputated arms ca. 8 days after amputation. After 54 days proximal, medial and distal regenerating arms had mean lengths of  $11 \pm 2$ ,  $8 \pm 2$  and  $4 \pm 1$  mm; dry weights of  $0.041 \pm 0.016$ ,  $0.020 \pm 0.007$ ,  $0.008 \pm 0.002$  mg and amounts of organic matter of 0.006, 0.003 and 0.001 mg, respectively. This confirms the relation between regeneration rate and position of amputation. It is well known that regenerative growth of an organ is more rapid than normal and gradually decreases until it becomes normal after the organ attains proper relative size (Huxley 1932, Goss 1969). The regeneration rate of an arm in *L. clathrata* declines as the asymptotic length is reached (Lawrence and Ellwood 1991, Pomory and Lares 2000). This suggests similar mechanisms of control occur in the two situations, both depending on the relative position of the regenerating arm tip.

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### Regularity and Pentamery in Sea Urchin Evolution

J. LÓPEZ-SAUCEDA AND J. L. ARAGÓN

The property of regularity has been a useful tool for the morphological description of organisms; radial symmetry implies regularity while bilateral symmetry irregularity. Sea urchins belong to a biological group showing radial and bilateral pentameric symmetry. In this work, we propose the use of eutacticity (a property related with stars of vectors) as a formal mathematical measure of regularity in sea urchins and this is applied to the study of apical disc variability through geological time. In our study, a star of five vectors is associated with each specimen using ocular plates, and thus a measure of eutacticity can be associated to each specimen. Our statistical analysis suggests a high degree of regularity (i.e., eutacticity) in the pentamery of the apical disc during the evolution of sea urchins, even considering symmetry variability in bilateral specimens. We observe that the Holasteroida Order (whose morphological and ecological traits are uncommon) is an antieutactic group (irregular) and its biological implications are discussed. Additional results suggest that pentamery favors regularity, in contrast to tetramery or hexamery. We conclude that regularity, as a mathematical tool, can generate interesting data about structural possibilities in the architecture of organisms.

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## Interactions of Food Availability and Small-Scale Turbulence on Grazing and Growth of Sea Urchin Larvae

E. M. MALDONADO AND M. I. LATZ

Food availability regulates the rate of development and larval quality of marine invertebrates, thus affecting length of the larval period, dispersal potential, and post-metamorphic juvenile survival. This study investigates whether small-scale turbulence increases food availability and enhances growth in sea urchin larvae as seen in zooplankton and fish larvae. Model predictions for passive larvae predict that turbulence should help them overcome food limitation by increasing the rate of predator-prey encounters and, consequently, ingestion rate. However, model predictions incorporating the feeding behavior and morphology of echinoderm larvae predict that environmentally relevant levels of turbulence should have no effect on prey encounters and ingestion rate. Model predictions were tested by maintaining larvae of the white sea urchin *Lytechinus pictus* at limiting and satiating food concentrations under either small-scale turbulence or still conditions. Grazing and ingestion rates of larvae were determined based on changes in cell concentration of the prey *Rhodomonas lens*. Growth was assessed by measuring morphological indices (e.g., postoral arm, midline body, and stomach lengths) and protein content, and determining developmental stage. There were no significant differences in grazing and growth of larvae exposed to small-scale turbulence compared to larvae in the still controls, confirming model predictions that ocean levels of turbulence would not affect grazing. These results suggest that enhancement of feeding due to turbulence depends on feeding behavior and morphology of the predator. This study is the first demonstration that small-scale turbulence has a different effect on the grazing and growth of marine invertebrate larvae, compared to fish larvae and other zooplankton, because of their different feeding behavior.

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## Strain Experienced by Eggs of *Pseudechinus magellanicus* During Spawning

E. M. MARZINELLI, G. BIGATTI, P. E. PENCHASZADEH, AND M. I. BROGGER

Sea urchins spawn large numbers of eggs into the water column where fertilization takes place. In some species, the size of the eggs is greater than the size of the gonopores. Eggs experience strain resulting from compression during spawning, which can affect fertilization. *Pseudechinus magellanicus* is an abundant urchin off the coast of Patagonia. In Golfo Nuevo, Argentina, the major spawning occurs in winter. Mean fresh egg diameter was 122 microns with a jelly coat of 49 microns. There was a positive correlation between test diameter and gonopore size, but egg size did not vary with test diameter. Egg strain was 0.47–0; small mature individuals (less than 15 mm test diameter) were the most affected by this strain. The presence of the jelly coat on eggs of this species may, however, reduce the effect of strain forces and prevent damage of the eggs during spawning.

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## Behavioral Interactions of the Antarctic Keystone Sea Star *Odontaster validus* With Three Sympatric Predatory Sea Stars

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*Odontaster validus* is ubiquitous in the nearshore marine benthos of Antarctica. Despite its ecological importance, little is known of its behavioral interactions with other common sympatric sea stars. We employed time-lapse video analyses conducted in a large laboratory tank (1.8 m diameter circular tank, 1,629 L). In each experimental trial, 34 adult *O. validus* were placed in a tight circular grouping on one side of the tank, and one adult individual of one of three common sympatric species of predatory sea star (*Labidiaster annulatus*, *Diplasterias brandtii* or *Perknaster aurorae*) was placed on the opposite side of the tank. Digital images of sea star movements were then captured at 1-min intervals over a 24-h period and aspects of sea star movements subsequently analyzed. Our results indicated that *O. validus* displays virtually no chemical or tactile behavioral responses to the large multi-armed *L. annulatus* and only weak tactile responses to *D. brandtii*. In marked contrast, *O. validus* had elevated levels of activity in the

presence of *P. aurorae* (potential chemically mediated response), and displayed a distinct “flight response” (change in direction and 2–6 fold increase of speed) upon tactile contact with this species. Moreover, an “alarm response” was detected when individuals of *O. validus* that encountered a fleeing conspecific also fled the vicinity. These contrasting patterns of behavioral responses provide an important predictive framework for future field-based evaluations of how interspecific sea star interactions impact the ecology of the Antarctic marine benthos.

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### Life History of the Deep-Sea Asteroid *Henricia lisa*: Reproductive Cycle, Aggregation, Spawning, Development and Early Growth

A. MERCIER AND J.-F. HAMEL

Combining field and laboratory work, this study investigated the biology of the sea star *Henricia lisa* living at bathyal depths off eastern Canada. Marked differences were found between individuals from deep (ca. 1,300 m) and shallower (ca. 600 m) locations. The former had a male biased sex ratio and an aperiodic reproductive cycle, whereas the latter displayed an equal sex ratio and a biannual breeding pattern. Furthermore, the maximum size was larger and female fecundity roughly five times higher in shallower compared to deeper populations. In the tanks, aggregative behaviour was recorded twice a year during the summer and winter breeding periods. The onset of aggregations and spawning coincided with a temperature of 3–4°C. Males spawned first and females typically responded inside 30–60 min. Between 12 and 20 eggs were retained to be brooded under the arched arms of the female, whereas the remainder were broadcasted and developed without parental care. The fertilized eggs underwent a first cleavage after 12 h, reached the brachiolaria stage in 1-mo, became juveniles within 3–4 mo and reached ca. 4 mm in diameter after 14–17 mo of growth. The embryos and juveniles developed at the same rate whether brooded or not, and development of winter cohorts was typically slower due to lower prevailing temperatures. This study of *H. lisa* provides the first evidence of lecithotrophy in a seasonally breeding deep-sea echinoderm and of brooding in a deep-sea asteroid.

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### A Revision of the Atelecrinidae, a Family of Unusual Unstalked Deep-Water Crinoids

C. G. MESSING

The Atelecrinidae, a family of unusual living unstalked crinoids from bathyal depths, is revised. A new genus is erected to accommodate the species *Atelecrinus wyvilli*, *A. conifer*, *A. cubensis* (restored from synonymy under *A. balanoides*), and a new species. A primary character of the new genus is the articulation of centro-dorsal and basals via five large interradial ligament bundles in place of a synostosis. *Atelecrinus* retains *A. balanoides*, *A. helgae* (status uncertain), *A. sulcatus* (restored from synonymy under *A. wyvilli*), and a new species previously treated as a bathymetrically allopatric form of *A. balanoides*. Examination of new material of five-armed *Atopocrinus sibogae* removes it from the Atelecrinidae, while a re-examination of the unique holotype of *Sibogacrinus anomalus* retains it within the family. Members of the Cretaceous genus *Jaekelometra* appear to fall outside the Atelecrinidae as well.

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### Holothurians of Kosrae (Federated States of Micronesia) and Majuro (Marshall Islands)

F. MICHONNEAU, S. KIM, AND A. M. KERR

In spring 2008, we investigated the sea cucumber faunas of the Micronesian islands of Kosrae (Federated States of Micronesia) and Majuro (Republic of the Marshall Islands). In Kosrae, we collected 34 species of holothurians (31 Aspidochirotida, 3 Apodida, 1 Dendrochirotida) in 13 days of survey; nine are new records and four are potentially undescribed species (one belonging to the genus *Actinopyga*, one to the genus *Bohadschia*, one to the genus *Labidodemas* and two to the genus *Holothuria*). Kosrae is now known to host no less than 35 species of sea cucumbers. We also sampled the Majuro atoll for 6 days and collected 27 species (20 Aspidochirotida, 6 Apodida, 1 Dendrochirotida). Seven of them seem to be new records for the Marshall Islands. Among them, we may have found

*Euapta tahitiensis* which is currently known only from the type specimen. The species richnesses reported here may be underestimated given that molecular analyses may reveal new cryptic species among the collected specimens in both islands.

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## Speciation in Aspidochirotid Holothurians

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Understanding and management of coral reefs depend fundamentally on our ability to distinguish and identify species, in conjunction with knowledge on their origin, distribution and biological characteristics. Yet available information on reef biota remains often inadequate and difficult to access. Aspidochirotid sea cucumbers are a case in point: they include the largest and most conspicuous motile invertebrates on reefs, and are often severely overfished because of their economical value. Identification of some harvested species, even though common, is problematic. We are undertaking a revision of these organisms. Here we present results from a molecular phylogeny on 250+ taxa, based on 2 mitochondrial gene regions. Results provide new insights into species limits. Heavy reliance on ossicles has led to a confused taxonomy and masks substantial cryptic diversity. The latter is exemplified by the circumtropical "species" *Holothuria impatiens*. This species complex has been revealed to consist of at least ten reciprocally monophyletic, well-defined, evolutionary significant units (ESUs). Each major tropical region has at least one endemic ESU; the East Pacific and Indo-West Pacific (IWP) host multiple taxa. The latter includes peripheral, archipelagic endemics as well as ESUs that range across the entire IWP. Broad overlap in the range of some in combination with recent divergence indicates the rapid evolution of reproductive isolation barriers among these ESUs. Morphological distinctiveness of ESUs vary: some show differences in ossicle morphology, others in live coloration, yet others show no morphological differences that we have been able to discern to date. These results are leading to a better understanding of the varied diversity and diversification mechanisms of reef organisms.

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## Down the Hatch: Star-Eating Gulls in Monterey, California

P. MONTEFORTE, J. B. MCCLINTOCK, K. E. VICKNAIR, H. M. FEDER, AND J. S. PEARSE

We present photographs documenting Western gulls (*Larus occidentalis*) swallowing whole sea stars on the breakwater of Monterey, California. In all cases, the prey were adult individuals of *Pisaster giganteus*, a predominately subtidal species that is occasionally exposed at low tides. Although individuals of the more abundant, predominately intertidal species, *P. ochraceus*, were often seen overturned with their ambulacral system pecked clean, none were recorded being eaten whole. Specimens of *Patiria miniata* were also photographed overturned by gulls, but their ambulacrals were not pecked clean. Gulls swallowing whole specimens of the predominately subtidal *Pisaster brevispinus* have also been seen elsewhere in Monterey Bay (JP). In addition, gull predation on a variety of intertidal sea stars has been reported for many places and is not uncommon (Google: gull predation sea stars starfish). The impact of gull predation on sea star populations has never been carefully studied. Nevertheless, the recently documented decline of intertidal sea star populations at sites in Monterey Bay may result, in part, from gull predation (Pearse, JS, McClintock, JB, Vicknair, KE, Feder, HM. in press. Proceedings International Echinoderm Conference, Durham, New Hampshire, 2006.)

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## Behavioral Effects of Light on the Tropical Holothurian *Pearsonothuria graeffei*

J. R. NESTLER, J. T. MAGI, AND S. B. PATTEN

Holothurians influence ocean communities by affecting physical and chemical characteristics of water and sediment through their deposit feeding and excretion activities. *Pearsonothuria graeffei* inhabits coral reefs in the



Indo-Pacific region and is active during the day and inactive at night. Daily cycles of behavior may be triggered by environmental cues such as food supply, tides, predation, temperature, or light. To investigate the role of light in the behavioral patterns of this species, movement, feeding status, and anus position were observed in situ during dawn and dusk as well as during light manipulation experiments. Data were collected at depths of 10–20 m using SCUBA. During dawn, *P. graeffei* began feeding significantly earlier than lowering the anus and initiating movement (repeated measures ANOVA, Newman-Keuls post-hoc test,  $p = 0.0006$ ,  $n = 11$ ). At dusk, feeding stopped significantly later than lifting the anus and ceasing movement (repeated measures ANOVA, Newman-Keuls post-hoc test,  $p < 0.0001$ ,  $n = 13$ ). During the night, exposure to artificial light caused inactive *P. graeffei* to become active (Fisher's exact test,  $p < 0.0001$ ,  $n = 9$ ). During the day, blocking light from active organisms did not significantly alter their activity state (Fisher's exact test,  $p = 1$ ,  $n = 8$ ). Artificially extending the light period during dusk significantly extended the active period of test subjects by  $32.2 \pm 14.2$  min (mean  $\pm$  SEM) compared to undisturbed surrounding individuals (one-tailed t-test,  $p = 0.0267$ ,  $n = 9$ ). Artificially extending the dark period during dawn significantly extended the period of inactivity by  $41.2 \pm 10.3$  min (mean  $\pm$  SEM) in the test subjects compared to surrounding undisturbed individuals (t-test,  $p = 0.0078$ ,  $n = 7$ ). These results suggest that light is an important exogenous stimulus that determines daily activity cycles of *P. graeffei*.

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### Biochemical and Energetic Composition of the Sea Urchin *Lytechinus variegatus* Under Regular and Upwelling Oceanographic Conditions

N. NORIEGA AND P. MILOSLAVICH

The upwelling systems represent an ideal natural scenario to examine the relationship between coastal oceanographic conditions, particularly temperature and food availability, and their effect on the reproductive cycle and energy investment in reproduction and growth. In Venezuela, an important upwelling system is located in the east of its Caribbean coast and is responsible for one of the most productive areas in the Caribbean. Populations of bivalves have been reported to reproduce during the upwelling season. In this study, we propose that the different conditions found in upwelling (east coast: Mochima) and regular (central-west coast: Morrocoy) conditions may affect gametogenesis, larval development, and the biochemical and energetic composition of the sea urchin *Lytechinus variegatus* during its reproductive cycle. We will conduct monthly sampling to determine the proximal composition and energetic content of the gonads, stomach and test, as well as examine larval development at different conditions of food availability and temperature that simulate upwelling ( $\sim 18^\circ\text{C}$ , high phytoplankton concentration) and regular ( $\sim 26^\circ\text{C}$ , low phytoplankton concentration) conditions. Low temperatures are known to slow metabolism, reproduction and gametogenesis, processes that require energy derived from food. Similarly, larval survival and growth are dependent on phytoplankton concentration. Our work will test the effects of these different and combined physical conditions on the energetic and biochemical balance of *Lytechinus variegatus*. A first experiment raising larvae at  $18^\circ\text{C}$  under high phytoplankton concentration resulted in metamorphosis to juveniles in 40 days. This represents a much longer development time than that reported for this species under warmer conditions (11 to 25 days).

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### The Cucumber Tree: Phylogeny and Evolution of Holothurians, With a Focus on Aspidochirotids

G. PAULAY, A. KERR, F. MICHONNEAU, K. NETCHY, S. MCPHERSON, M. O'LOUGHLIN, AND J. STARMER

As part of revisionary effort on holothurians we are sequencing multiple specimens of all available species, to help test species limits and construct phylogenetic hypotheses. We are taking a bottom up approach, focusing on species level taxonomy first and then building larger-scale phylogenetic hypotheses as warranted by available samples and sequences. Thus mtDNA markers (especially COI and 16S) are sequenced first, as they are most informative at low taxonomic levels, followed by nuclear markers (currently 28S, 18S, ITS). We now have sequences from 90 genera and subgenera spanning the class, and >350 species. Many interesting results are emerging from these analyses, with preliminary results suggesting the following. Non-monophyly is prevalent at all levels, and numerous well-known species consist of multiple taxa. Apodans are holding as the most divergent group. Stichopodids appear to emerge from paraphyletic synallactids. Holothuriids appear monophyletic and Cuvierian tubes are one synapomorphy of the family. *Holothuria* is non-monophyletic, with *Panningothuria*,

*Platyperona*, and *Microthele* especially deeply divergent. Several *Holothuria* subgenera (*Holothuria* s.s., *Vaneyothuria*, *Selenkothuria*, *Semperothuria*, *Halodeima*) appear to form a robust, rapidly radiating clade characterized by unusual ossicles—modification or loss of buttons (often into rosettes or rods) and tables. We will present the latest phylogenetic hypotheses and analyses of character evolution available at the time of the meeting.

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## Echinoderms Collected by the U.S. Fish Commission Steamer *Albatross*, 1882–1920

D. L. PAWSON AND D. J. PAWSON

During her long and distinguished 38-year career the *Albatross* collected a great number of echinoderms from the continental shelf to the abyss in the Atlantic and Pacific Oceans. Many trawl hauls brought up “tons” of echinoderms. Prominent echinoderm scientists who sailed on the *Albatross* include: Alexander Agassiz, three cruises; Walter K. Fisher and Austin H. Clark one cruise each. Kakichi Mitsukuri and Seitaro Goto joined the 1906 cruise as guests for several days. The echinoderm collections were studied by several contemporary world authorities, notably Alexander Agassiz, Hubert Clark, Austin Clark, Walter Fisher, Seitaro Goto, René Koehler, Hubert Ludwig, Kakichi Mitsukuri, Theodore Mortensen, and Hiroshi Ohshima. Today, *Albatross* echinoderms are still being studied, and new taxa described. In total, more than 1700 new species have been described to date—approximately 25% of the extant echinoderm species. The *Albatross* echinoderms are a surprisingly large component of the type- and non-type collections in several major museums.

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## The Compleat Echinodermologist: John Miller Lawrence

J. S. PEARSE

Raised in the rolling hills of southern Missouri, John Miller Lawrence discovered echinoderms as a graduate student in California. Before he completed his doctorate at Stanford University in 1966, he had published papers on echinoid digestion in both *Science* and *Nature*. And he never looked back. His phenomenal 42-year long career on the faculty of the University of South Florida established him as one of the most productive and influential echinoderm biologists of the 20th century. To date he and his students have published 194 refereed papers, covering all aspects of echinoderm physiology and ecology, plus another 24 invited chapters in edited books. His “On the relationships between marine plants and sea urchins,” published in *Oceanography and Marine Biology, An Annual Review* in 1975, is a classic that heralded a new field of subtidal ecology and introduced us to the concept of “urchin barrens.” His 1987 *A Functional Biology of Echinoderms* summarized knowledge of our favorite animals from a fresh perspective. He edited and co-edited 11 books, including the 6-volume series *Echinoderm Studies*, as well as the authoritative *Edible Sea Urchins: Biology and Ecology*, which now in its 2nd edition (2007) provides the cornerstone to the growing sea urchin mariculture industry. But he has hardly been a reclusive scholar. He has presented 193 talks at conferences and meetings, 11 invited, and organized major conferences himself. He has mentored 45 of his own graduate students, 11 doctoral, plus innumerable students around the world. Indeed, John has made it his business to go where the echinoderms are, from France, Israel, and Japan to Kerguelen, New Zealand, and Chile. Everywhere, his laughter and infectious enthusiasm are well known. It is my pleasure to pay tribute to my long-time colleague and friend, who “retired” in 2007 but continues to celebrate echinoderms in the 21st century.

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## Scaling of Aristotle’s Lantern in *Lytechinus variegatus* (Echinodermata: Echinoidea)

C. M. POMORY AND M. T. LARES

Changes in body proportions have functional consequences for the biology of animals. Conversely, functional constraints limit the degree of change. Sea urchins feed on solid food with the Aristotle’s lantern, a complex calcified apparatus consisting of five main pieces known as pyramids. The objective of this study was to determine how pyramid length and mass relate to body size (measured by test diameter) as sea urchins grow from small

juveniles to adults. *Lytechinus variegatus* ranging in size from 8–56 mm test diameter were collected from Port St. Joe, Florida. After extraction and cleaning with bleach, a randomly selected pyramid was measured from each individual. The relation between pyramid length and test diameter was linear over the size range measured (slope of regression = 0.23). The relation between pyramid mass and test diameter could be divided into two distinct phases: an initial slow-increase phase (<25 mm test diameter, slope of regression = 1.5), and a later fast-increase phase (>25 mm test diameter, slope of regression = 7). The relation between ln pyramid length and ln pyramid mass was linear with a slope near 3. This suggests that somewhere in the size range 22–28 mm test diameter a major functional or morphological change takes place during the growth of this sea urchin with pyramid mass being affected to a much greater degree than pyramid length. A small test may impose internal volume constraints in relation to how large a size the Aristotle's lantern can attain. Increase in mass may facilitate feeding in larger individuals by making the structure of the lantern more robust.

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### The Effect of Diet on Coelomocyte Cell Populations in the Sea Urchin *Lytechinus variegatus*

M. L. POWELL, V. K. GHANTA, A. R. NELSON, A. L. LAWRENCE, AND S. A. WATTS

Coelomocytes are implicated in the innate immune response in sea urchins. We have identified five coelomocyte types in *Lytechinus variegatus*: phagocytic amoebocytes, dendritic amoebocytes, vibratile cells, red spherule cells, and colorless spherule cells. To characterize a potential immune response in *L. variegatus*, 100 µg lipopolysaccharide (LPS) in 600 µL sterile seawater was injected to simulate a bacterial infection. Coelomic fluid (100 µL) was removed and mixed with an equal volume of 10% EDTA in sterile artificial seawater, for differential cell counts at 0, 1, 2, 3 and 4 hours following LPS injection. Dendritic cell numbers doubled in the first hour and remained elevated for 2 hours, colorless spherule cells increased at 2 hours and returned to control levels within 1 hour. In addition, recent work in our laboratory suggests that the coelomocyte population can be affected by diet. Fructo-oligosaccharide (FOS) is a probiotic shown to benefit gut microflora and possibly immune function in vertebrates and invertebrates. The effects of pre-biotics on the sea urchin gut are not known. To evaluate the effect of a pre-biotic diet on coelomocyte populations, *L. variegatus* were fed ad libitum for 12 weeks feed containing 0%, 0.5% or 1% FOS. Differential coelomocyte counts revealed an increase in the number of white spherule coelomocytes and a decrease in the number of dendritic cells with feeds containing FOS compared to the 0% FOS diet. Whether this shift in coelomocyte populations will affect immune response is currently under investigation. These data support the hypothesis that diet can influence the coelomocyte population and potentially the immune activities of *L. variegatus*.

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### Observations of Cannibalism in Lab-Reared *Lytechinus variegatus* (Echinodermata)

C. M. RICHARDSON AND S. A. WATTS

When held in captivity *en masse*, adult *Lytechinus variegatus* will cannibalize other *L. variegatus* in the tank. In observations to date, individuals consumed showed no signs of injury or disease. Cannibalism occurred when a predatory urchin first consumed the spines of a conspecific prey urchin, usually on the aboral surface first, followed by consumption of all spines. In general, the predator urchin would then remove the lantern and consume it completely prior to breaking the test and consuming, in part or completely, the test and the gonad. In many cases the gut tissues were not consumed, suggesting some level of aversion to this organ. In some cases, prey urchins were able to escape by apparently dropping spines and moving rapidly away from the predator urchin. Cannibalistic behavior has recently been observed in dense populations of developing juveniles. In this study, juvenile *L. variegatus* (<2mm diameter) were placed in small finger bowls and observed for up to 2 weeks. Individuals were not fed during the 2-week period. Previously-starved juveniles showed minimal cannibalism when held at densities of either 1,600/m<sup>2</sup> or 1,000/m<sup>2</sup> (<7 %). Cannibalism increased to 23% in juveniles fed previously and then transferred to finger bowls for 2 weeks at 1,600/m<sup>2</sup>. We suggest that nutritional history, size, and density will contribute to the rate of cannibalistic behavior in cultured sea urchins. This is the first report of conspecific cannibalism in any sea urchin species.

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### Chemical Tagging Assay on the Ophiuroid *Ophioplocus januarii* Growth

M. S. RODRÍGUEZ, P. E. PENCHASZADEH, AND M. I. BROGGER

Chemical tagging of organisms to provide identification or measure growth has been used successfully in many studies. The chemicals calcein and alizarin red incorporate a measurable fluorescent mark into the skeletons of a wide variety of taxa. The purposes of this study were to evaluate if calcein and alizarin red affect survivorship of the ophiuroid *Ophioplocus januarii*, and to determine where measurable fluorescent growth marks may appear. Growth of *O. januarii* was compared under starvation in two treatments: at 2 concentrations (100 and 200 mg/l) under different time period of bath exposure (3 and 6 hours) or by injecting chemical tags directly into the coelomic cavity. For this ophiuroid, we found the concentration of alizarin red leaves no evidence of a mark on the skeleton. However, individuals that had been marked with calcein showed a distinct green fluorescent mark in all the analyzed samples. Particularly, jaw marks were ubiquitous and well defined in most of the individuals (93%). Mortality rate was only 1% over the experimental period. Calcein marks from bath treatments and coelomic injections were similar and independent of the solution concentrations or the hours of bath immersion. Even though injection was the most rapid technique and provided positive results, we assume that it induces stress. After a period of 2 months, some individuals ( $n = 6$ ) displayed a measurable growth increment extending beyond the fluorescent line, with a maximum tooth growth of 0.1 mm.

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### A Behavioral Response of *Asterias forbesi*: Sensing Umami

C. ROMNEY, E. CREASER, AND A. ARNETT

The effect L-glutamine has on the predatory responses of *Asterias forbesi* was examined in an experiment using food models and odor plumes that ranged in concentrations of  $10^{-2}$ ,  $10^{-4}$ ,  $10^{-6}$ , and 0, respectively. In the experiment, three common predatory responses to the models/plumes were sought after. These responses were: 1) raising of terminal tips of the rays (type I), 2) humping response (type II), and 3) full bodied attempt to consume (includes stomach eversion) (type III). The cause of the predatory responses was solely based on the concentration of glutamine used during each trial. Extensive care was taken to eliminate all possible impacting variables on the experimental results. The behavioral responses indicated that the sea star *Asterias forbesi* is positively attracted to L-glutamine and exhibits more pronounced positive responses as the concentration of glutamine is increased.

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### First Detection of TPep (Tritonia Pedal Peptide) in the Nervous System of the Fissiparous Starfish *Allostichaster capensis*

T. RUBILAR, A. F. SCHINDER, C. T. PASTOR-DE-WARD, AND M. I. BROGGER

The nervous system of the fissiparous starfish *Allostichaster capensis* was subject to immunocytochemical investigation using antisera raised against the gastropod neuropeptide Tritonia Pedal Ganglia (TPep). This peptide has been found in motoneurons as well in neurons located in the pedal ganglia of the gastropod *Tritonia diomedea* and it appears to be involved in motor functions. In the starfish, immunoreactivity was detected in the hyponeuronal and ectoneuronal systems, as well as the innervations of the tube feet. In the hyponeuronal system, the label is observed in numerous group cells bodies in the radial nerve cord as well as the circumoral ring. In the ectoneuronal system, the TPep immunoreactivity is observed in isolated neurons as well as in the neuropil, where a strong staining can be observed in the axon section.

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## Settlement Behavior and Early Post-Settlement Predation of the Sea Urchin *Strongylocentrotus droebachiensis*

R. E. SCHEIBLING AND M. C. ROBINSON

We examined behavior of competent larvae of the green sea urchin *Strongylocentrotus droebachiensis* provided with pebbles encrusted with coralline red algae, a strong settlement inducer, in laboratory experiments. Larvae settled at greater frequencies on upward-facing coralline surfaces and in small gaps between coralline and glass surfaces than expected by a random distribution of settlement. These patterns may be explained by encounter rate with inductive cues. There was no change in settler distributions within ~1 week of settlement, indicating no net movement between adjacent microhabitats. In flow, live and recently killed larvae settled or were passively entrapped at greater frequencies on high- than low-rugosity coralline crusts. Recent settlers (0.5–1 mm diameter) were consumed by small decapod crustaceans and bulldozed by periwinkles. Juveniles became less vulnerable to predation by hermit crabs with increasing size, and reached a growth refuge at ~10 mm. Our laboratory findings suggest that the cryptic distribution of recent settlers is probably not due to microhabitat selection by settling larvae or early post-settlement migration, at least not in response to physical cues such as light or surface texture. Differential rates of predation of young juveniles between exposed and cryptic habitats cannot be ruled out as an important determinant of this pattern.

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## Echinoderms on Alaskan Seamounts

T. C. SHIRLEY AND D. P. UNDERWOOD

The bathymetric and spatial distribution of echinoderms was examined on five seamounts in the Gulf of Alaska in 2004 using the manned submersible DSV *Alvin*. Replicate video transects of 200 or 500 m were surveyed at 700, 1,700 and 2,700 m; voucher specimens were collected. An oxygen minimum zone (<5% saturation) encompassed the shallowest depth sampled, from 500–1,500 m. Temperature decreased from 15°C at the surface to 1°C near the bottom (3,000 m); most transects were between 2 to 3.5°C. Asteroids were conspicuous mobile predators; average density was significantly related to depth:  $2.1 \cdot 100 \text{ m}^{-2}$  for the shallow depth category (700–1,100 m),  $1.0 \cdot 100 \text{ m}^{-2}$  for intermediate depths (1,650–1,711 m), and  $0.7 \cdot 100 \text{ m}^{-2}$  for the deepest depth (2,670–2,700 m). Six of the 11 asteroid species collected were Goniasteridae; Myxasteridae and *Evoplosoma* were range extensions; 3 goniasterid seastars were preying on corals when collected. Holothuroid density was  $20 \cdot 100 \text{ m}^{-2}$  at the shallow depth to  $0.4 \cdot 100 \text{ m}^{-2}$  at the deep depth. Holothuroid (*Pannychia* and *Psolus*) density for the shallow depth was significantly higher than at the deeper depths. Ophiuroid density for 3 genera (*Asteronyx*, *Amphigyptis*, and *Ophiomoeris*) was significantly higher on Dickens Seamount than on the other three seamounts. Average ophiuroid density was highest ( $140 \cdot 100 \text{ m}^{-2}$ ) on Dickens Seamount, and decreased to  $31 \cdot 100 \text{ m}^{-2}$  on Pratt Seamount. Ophiuroid density across seamounts was  $8 \cdot 100 \text{ m}^{-2}$  at the shallow depth,  $141 \cdot 100 \text{ m}^{-2}$  at the intermediate depth, and  $41 \cdot 100 \text{ m}^{-2}$  at the deep depth. Ophiuroid density was significantly higher at intermediate than the shallow and deep depths. Density of *Psathyrometra fragilis* and *Hyocerinus* sp. crinoids did not vary by seamount or depth, but was highest ( $3.2 \cdot 100 \text{ m}^{-2}$ ) at deeper depths. No echinoids occurred on transects, but were observed on three of the seamounts. Many ophiuroids were associated with paragorgiid and primnoid corals; other echinoderms were on rocky substrates; *Pannychia* were often on muddy bottoms. Echinoderms (all taxa combined) were most abundant ( $146 \cdot 100 \text{ m}^{-2}$ ) at intermediate depths of 700–1,100 m.

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## Performance of the European Sea Urchin Reared on Biofilter-Seaweed

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The sea urchin *Paracentrotus lividus* was introduced as a candidate species for commercial development in a fish, seaweed and sea urchin integrated system in Eilat (Red Sea), Israel. While the fish represented the main product, effluents from fish culture supported the growth of the macroalgae *Ulva lactuca* and *Gracilaria conferta*. Both seaweeds were used as a biofilter to remove dissolved nutrients from the water and as forage for the sea urchins. Sea urchin performances in terms of survival, growth, food conversion ratio (FCR), protein and

energy use, gonad development and color were evaluated. Growth from spawning to commercial size (45 mm) on the seaweed diet took approximately 36 months, FCR on a wet weight basis ranged between 5–7, and survival rates from settlement were 70–80%. Three months before harvest, prepared diets were administered to accelerate growth.

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### Regulation of Mitogen-Activated Protein Kinase During Oocyte Maturation and Fertilization in the Starfish

L. C. SHUHAJBAR, H. WEI, B. O. PENNINGTON, A. MANTILLA, AND D. J. CARROLL

The mitogen-activated protein kinase (MAPK) pathway may play a pivotal role during oocyte maturation and fertilization in the eggs of some animals. MAPK activity is phosphorylation-specific, increasing when the enzyme is phosphorylated on Thr202 and Tyr204. Using a phosphorylation-state specific antibody, we show that MAPK becomes phosphorylated during oocyte maturation in two starfish, *Asterina miniata* and *Pisaster ochraceus*, and then dephosphorylated following fertilization in *A. miniata*. To understand how MAPK is regulated during these transitions, we compare MAPK phosphorylation changes in single starfish oocytes to those observed in oocyte populations. Changes in MAPK phosphorylation are more abrupt when visualized in single oocytes than when oocyte populations are assayed. In individual *Asterina miniata* oocytes, MAPK becomes phosphorylated at 20 minutes following I-MA addition and dephosphorylated 20 minutes following insemination. MAPK becomes phosphorylated at 40 minutes following I-MA treatment in *P. ochraceus* oocytes and remains phosphorylated even 60 min following fertilization. *A. miniata* oocytes incubated with farnesyl transferase inhibitor III (FPT III) do not undergo germinal vesicle breakdown or MAPK phosphorylation in response to I-MA, suggesting that Ras is involved in this process. The single cell system will allow examination of the variability of individual oocyte response to differing stimuli. This is something that cannot be observed when working with samples prepared from populations of cells. It is hoped that this will allow novel mechanistic studies to understand the regulation of MAPK during oocyte maturation and at fertilization in much finer detail than has been possible thus far. This research was supported by NIH AREA Award R15 HD048712-01.

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### Growth Rate and Predation Pressure as Key Factors in the Management of *Cucumaria frondosa* (Holothuroidea) in Eastern Canada

J. J. SO, J.-F. HAMEL, AND A. MERCIER

As world sea cucumber fisheries decline, alternative species such as *Cucumaria frondosa* are being considered for future fisheries. In this study growth rates and predation pressure were investigated. Eight size classes of sea cucumbers were kept in tanks provided with running unfiltered seawater under natural conditions of photoperiod for a minimum of 16 months. The smallest size class was comprised of recruits obtained from spawning in the laboratory and monitored for 24 months. All size classes exhibited seasonal growth with increases in immersed weight after spring peaks of phytoplankton abundance. Overall growth rates were very low and negative trends were observed in some classes. No small individuals were found in the natural habitat on the Grand Banks, possibly indicating that populations are at their climax ( $0.51 \text{ ind m}^{-2}$ ), though the inadequacy of the sampling gear cannot be totally discarded. The main predator of *C. frondosa*, the asteroid *Solaster endeca* occurred sympatrically in almost all sites surveyed. The maximum density of *S. endeca* was  $0.05 \text{ ind m}^{-2}$  and its average abundance was ca.  $0.01 \text{ ind m}^{-2}$ . Under controlled laboratory conditions, *S. endeca* was found to consume 2–4 sea cucumbers per month. Its feeding rate was modulated by seawater temperature. Moreover, *S. endeca* preyed more intensely upon small sea cucumbers (ca. 7 cm in length) than large ones (ca. 14 cm). Based on these findings *S. endeca* can potentially remove an average of  $0.28 \text{ ind m}^{-2}$  sea cucumbers annually. Feeding trials also demonstrated that sea cucumbers damaged by trawling activities can attract sea stars, suggesting that predatory pressure could increase over time. The combination of slow growth rates and high predatory pressure enhanced by fishing activities emphasizes the need for a cautionary approach to managing this emerging fishery.

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### Mitochondrial DNA Gene Flow Analysis in North Atlantic Populations of the Sea Cucumber *Cucumaria frondosa* (Holothuroidea: Echinodermata)

J. J. SO, S. UTHICKE, J.-F. HAMEL, AND A. MERCIER

The dendrochirotid sea cucumber *Cucumaria frondosa* is the most abundant holothurian in the North Atlantic and is fished throughout its arctic and subarctic distribution. This species has high dispersal lecithotrophic larvae that can stay in the water column for up to 46 days, potentially providing recruitment to distant populations. Molecular techniques are becoming increasingly important tools for determining population structure and managing fisheries. In the present study, mitochondrial DNA (mtDNA) was extracted and sequenced from a total of 344 sea cucumbers collected from 20 locations (separated up to 5,900 km) throughout the North Atlantic. Hierarchical Analyses of Molecular Variance (AMOVA) indicated no significant population separation either between nine major geographic regions ( $\Phi_{CT} = 0.0017$ ,  $p > 0.05$ ) or between the Eastern and Western Atlantic ( $\Phi_{CT} = 0.0044$ ,  $p > 0.05$ ) and most variation (98.78%) occurred within populations. In addition, neither the  $\Phi_{ST}$  values nor corrected genetic distance (Kimura 2 Parameters) showed any signs for isolation by distance. In contrast, exact test for population differentiation was overall significant ( $p < 0.05$ ) and showed significant differentiation of several pairs of populations, irrespective of their geographic distance. This indicates that this species shows strong genetic patchiness as was recently described for several other marine species. Sporadic recruitment or low genetic variability in surviving larval recruits was previously suggested to explain that pattern. Thus most of the North Atlantic *C. frondosa* collected appear to be part of a large population connected through high gene flow facilitated by long larval life. Local genetic patchiness can occur however with variations in sources of recruitment over ecological time scales. An international management plan for this wide ranging population is needed to ensure a sustainable fishery for all countries. If genetic patchiness is confirmed, additional 'local' management would be required through closure of apparently less connected areas.

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### Diversity of Echinoderms at Isla Cocinas, Bahía De Chamela, at the Mexican Central Pacific

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Isla Cocinas is located in the Biosphere Reserve "Bahía de Chamela-Cuixmala", within the Municipio of la Huerta Mexican Central Pacific. Located approximately 120 km north of Manzanillo, Colima, Mexico (19°32.766'N 105°06.577'W), to date only the terrestrial area of the island is protected. The island is located approximately 2 km from the mainland. During a 5-day visit trip, we recorded 30 echinoderm species: Asteroidea (2 spp.), Ophiuroidea (6 spp.), Echinoidea (5 spp.), and Holothuroidea (17 spp.). Two potentially new species of holothurians were found. Although the Mismaloya-Chamela Bay is considered a priority site for deep sea conservation, the present knowledge of echinoderm biodiversity in this area is limited. This work provides important information relevant to the conservation and management of both Isla Cocinas and the Chamela-Cuixmala Biosphere Reserve complex as a whole.

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### Statistical Analysis of Tissue-Specific Ossicles in Holothurians

J. A. STARMER AND G. PAULAY

Analysis of ossicles from the body wall, along with gross morphology, is the basis of holothurian taxonomy. Great variation in soft tissue morphology of both living and preserved specimens has focused efforts in taxonomic

discrimination on the calcareous ossicles. Differentiation between ossicle types is generally based on gross descriptions of form, which are given names such as tack, button, rosette. However, variation in ossicle form, even within named forms within a single individual and certainly between a novel specimen and type descriptions, can challenge taxonomic identification. While ossicles have been known from tissues other than the body wall, they have been generally applied to taxonomic issues in a quantitative manner. By evaluating ossicles from tissues other than the body wall and by applying statistical analysis to ossicle measurements, additional quantitative informative characters are available for differentiating between holothurian taxa.

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### Systematics and Phylogeny of Stichopodidae (Aspidochirotida: Holothuroidea)

J. STARMER AND G. PAULAY

The Stichopodidae is a well known and conspicuous family of mostly shallow water aspidochirotids with 9 recognized generic taxa, and ~80 available and ~40 valid species. Through field work and from colleagues we have obtained fresh material of all genera and about 30 species, including several undescribed ones. We studied all of these morphologically, and successfully sequenced mitochondrial (COI, 16S) and, to a more limited extent, nuclear (28S, ITS) markers from 26 species representing 8 genera. Results indicate that these 8 genera are all monophyletic and robust, although not always as presently constituted. *Stichopus*, the most diverse genus, is limited to the Indo-Pacific and sister to *Isostichopus* from the Americas. Similarly, the Indo-West Pacific *Theleota* is sister to the W Atlantic *Astichopus*, as previously suggested on morphological grounds. *Eostichopus*, *Parastichopus*, *Apostichopus*, and *Australostichopus* are all distinct and deeply divergent. However NE Pacific stichopodids do not belong to *Parastichopus* but should be transferred to *Apostichopus*, while "*Eostichopus*" *regalis* is a *Parastichopus*. We explore the radiation of stichopodids in morphological and biogeographical terms.

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### UV Effects on Larval Biology of *Lytechinus variegatus* (Echinodermata: Echinoidea)

E. C. TAUGHMAN AND C. M. POMORY

Ultraviolet radiation (UV) at Earth's surface increases in conjunction with decreases in stratospheric ozone. Stratospheric ozone has decreased due to air pollution from human activity. Elevated UV levels have detrimental effects on biological function. Effects of UV exposure on the development of marine larvae were examined using the tropical/subtropical sea urchin *Lytechinus variegatus*. Larvae were exposed to 30 minutes of ecologically relevant doses of UV at the blastula, gastrula, or pluteus stage of development. Larval arm length, which correlates with feeding capability, was measured to quantify UV effects. Percent metamorphosis was recorded to see if larval stress affects the process of metamorphosis from larva to juvenile. Differences due to stage of exposure were apparent in arm lengths and percent settlement of larvae. Larval arm length was reduced by UV exposure in the blastula and gastrula stages of development. Percent settlement declined with UV exposure in the gastrula and pluteus stages of development. Both results suggest timing of exposure relative to developmental stage should be important in determining how larvae respond to changes in UV levels in the natural environment.

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### Community Structure of Echinoderms in the Only Pristine Area of Western México

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Recent comparative studies have revealed that community structure can be dramatically different between regions with a long history of fishing compared with those where human influence is minimal. In México, the Marias Islands Biosphere Reserve, located about 100 km off the Pacific coast, is the best example of a pristine marine environment. This archipelago has harbored a high security prison since the 1920s, and thus provides conditions of isolation and minimum exploitation of marine resources. To describe the conditions of this area and make comparisons with others in similar reef environments, in July 2007 we visited the four islands of the Reserve (María



Madre, María Magdalena, María Cleofas and San Juanito), as well as Isabel Island (at the same latitude but where fishing occurs). For each island, we determined community structure of representatives of the Asteroidea, Echinoidea and Holothuroidea. Data were obtained via 25 × 2 m long belt transects (N = 68), from which we calculated density (ind/m<sup>2</sup>), species richness, diversity (H') and evenness (J'). The results indicated that sea stars were significantly more abundant in San Juanito Island and the dominant species was *Phataria unifacialis*. Ecological indices did not differ among islands. For sea urchins, all islands had similar richness, abundance and diversity, with the one exception of San Juanito where very few individuals were seen. Finally, holothurians were so scarce that no differences among indices were significant, although María Magdalena had the greatest abundance and richness (*Isostichopus fuscus* dominated). Comparing community structure of urchins and sea stars of Mariás Islands and Isabel Island, there were significant differences in abundance and richness, although urchin diversity and evenness did not differ between sites. We conclude that the remarkable differences observed between Isabel and the Mariás Islands demonstrate the effect of human activities on the reef ecosystem, and that these effects are evident even in non-exploited species.

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### Effects of Dietary Zinc on Growth and Reproduction of the Sea Urchin, *Lytechinus variegatus*

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Zinc is an important mineral implicated in a number of cellular processes in sea urchins, and is considered important for gamete development in preparation for early embryonic development. Zinc is available in sea water, or can be obtained in the diet. This study examined the effects of dietary zinc on the growth and reproduction of the sea urchin, *Lytechinus variegatus*. Adult sea urchins were randomly separated into different treatment groups, and were fed one of seven formulated feeds that were supplemented with different levels of dietary zinc (4.5, 10.8, 26.3, 65, 162, 403 or 1,005 ppm calculated). After 9 weeks, the sea urchins were dissected and wet and dry weights of the organs were measured. The zinc did not significantly affect test or gut weight gain. However, those individuals fed the lowest level of dietary zinc (4.5 ppm) produced a smaller gonad with reduced moisture content. These data suggest a dietary requirement for zinc. The sea urchins fed 1,005 ppm zinc had a significantly smaller lantern, suggesting that urchins fed very high levels of zinc will experience some pathology. Supported in part by the Mississippi-Alabama Sea Grant Consortium.

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### A New Kind of Pedicellaria of Echinoderms

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Echinoderms are known for their pedicellariae, which are reported so far only from echinoids and many asteroids. Pedicellariae are not, therefore, a synapomorphy and probably evolved independently at least twice. A pedicellaria consists of at least two modified spines (valves) that articulate on a base, either a plate or a pedicel. There are many kinds of pedicellaria in both classes, including globiferous, tridentate, and triphyllous among echinoids and straight, sugar-tong, and felipedal in asteroids. Here we describe a new kind of pedicellaria from four gorgonocephalid ophiuroids, specifically *Astracme mucronatus*, *Asteroporpa annulata*, *Astrophyton muricatum*, and *Astrocyclus caecilia*. In these species, the pedicellaria consists of several hooklets (previously described for many gorgonocephalids) arranged in two opposing rows on a base plate on the dorsal surface of the terminal arm segments. Each hooklet articulates on a tubercle that has a central pore (presumably to receive a ligament), a broad medial region of relatively imperforate stereom (as a bearing surface), and a peripheral region of labyrinthic stereom (probably for attachment of muscle). Hooklets are not directly opposite each other but slightly offset, giving the appearance of a claw clip used in hairstyling. The manner in which hooklets overlap might give the same effect as crossed pedicellariae in asteroids. The association of the ossicles with soft tissues is not yet known. We name this new type "claw-clip pedicellaria". Attempts to capture the action of live pedicellariae by videography are underway.

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### Embryonic and Larval Development of the Sea Urchin *Cassidulus mitis* (Echinoidea: Cassiduloidea): “Living Fossil” Endemic of Brazil

C. R. R. VENTURA AND M. V. CONTINS

Extant species of cassiduloids show distinct signs of “character exhaustion”. It means that no significant novelties in morphology have arisen since the late Cretaceous. *Cassidulus mitis* is considered to be a living fossil because it belongs to an old lineage and shows primitive morphological characteristics in its body plan. The present study aims to describe the chronology of the early development of *C. mitis*, from embryo to juvenile recruitment. *Cassidulus mitis* has large oocytes (250 µm) and develops a lecithotrophic epibenthic larva. Oocytes and embryos are kept among spines during the early developmental stages by females. The individuals were collected by snorkeling at the Vermelha Beach, RJ. The females that had embryos among their spines were kept to be monitored. Before the fertilization, 2 mL of the 0.5 M solution of KCl was injected in the coelomic cavity to stimulate spawning. After the crossing, eggs were kept in aquaria under constant temperature (20°C) and each developmental stage was photographed under a dissecting microscope. The time required for a recently fertilized cell to develop into an echinopluteus larva is 6 days. Cleavage becomes visible about 1-hr after fertilization. The gastrula develops by the 2nd day after fertilization followed by larva development. On the 5th day, a 4-armed larva is formed. After 9 days, the larva starts to lose its form, becoming more irregular in shape. On the 11th day, metamorphosis is initiated and on the 16th day the early juvenile is formed. In conclusion, the entire early development of *C. mitis* lasts about 17 days, from fertilized egg to post-settlement juvenile. *Cassidulus mitis* is an endemic cassiduloid with low dispersal capacity. Information about its development may provide insights into understanding the life history of extinct ancestors and is also important in the prevention of modern extinctions.

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### Morphological Comparison Among Color Morphs of *Paracentrotus gaimardi* (Blainville) (Echinodermata: Echinoidea)

C. R. R. VENTURA AND E. M. LOPES

Five color morphs of *P. gaimardi* can be distinguished: brownish (Br), grayish (Gy), blackish (Bl), pinkish (Pi), and greenish (Gr). The present study aims to compare morphologically the morphs regarding its original diagnosis. Thirty sea urchins of each morph were placed individually in a dilute solution of NaClO for 5 min. Each solution was then filtered through 50 µm mesh and diluted in 10 ml distilled water. Percentages of each type of pedicellaria per individual were estimated by counting in a Sedgewick-Rafter cell and was compared using a  $\chi^2$  Test. Types of pedicellaria, their distribution on the test and the apical system of each specimen were observed under a dissecting microscope. Linear regressions between the mean numbers of tubercles on the genital plates and the diameters of the tests were calculated for each morph. The significance of each regression was estimated and their slopes were compared using a Student's *T* Test. No significant difference was found regarding the mean number of each pedicellaria type among morphs ( $\chi^2$ ,  $p > 0.001$ ). Triphyllous was the most common pedicellaria type, followed by ophicephalous, globiferous, and tridentate. The relation between the mean number of tubercles and the test diameter was significant in the Br, Gy, Pi, and Gr morphs. This relationship was different between the Gy and Pi, Gr and Pi, Gr and Gy, and Gr and Bl morphs. Distribution patterns of pedicellariae on the test were: large globiferous form on the aboral surface, smaller globiferous form on the oral surface; both tridentate pedicellaria types found on the oral region; triphyllous and ophicephalous pedicellariae widespread on the test surface; and small ophicephalous pedicellariae with large bases present around the mouth. The pattern of pedicellaria distribution and the smaller ophicephalous type may be considered as new morphological characteristics of *P. gaimardi*. In contrast, the number of tubercles on genital plates shift according to size and color morph.

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### Modeling the Somatic Growth and Estimating the Mortality of the Living Fossil *Cassidulus mitis* (Echinoidea: Cassiduloidea), an Endemic Species of Brazil

C. R. R. VENTURA AND R. S. VAROTTO

The somatic growth and mortality of the endemic echinoid *Cassidulus mitis* Krau, 1954, were analyzed in the present study. Echinoids were sampled monthly for size distribution analysis and mark-recapture experiments

were also conducted. Estimating parameters for growth curves defined by four different models by means of non-linear regressions (Brody-Bertalanffy, Richards, Gompertz, and logistic models) and for the natural mortality of the population were calculated. Evaluation of the models was based on (1) analysis of the sum of the square residuals from the former non-linear regressions, (2) analysis of the distribution of these residuals, and (3) comparison of linear regressions between predicted and observed sizes of the recaptured specimens. The curves assigned by both the Gompertz's equation and Brody-Bertalanffy's model were considered the best candidates for describing the growth of *C. mitis*, although Gompertz's model seems to be more appropriate. Further information of the time span of the early developing phase is still needed to define the best growth descriptor to *C. mitis*. Growth and mortality constants predicted by Gompertz's model were  $0.53 \text{ year}^{-1}$  and  $0.61 \text{ year}^{-1}$ , respectively. Analysis of the growth curve shows that *C. mitis* becomes mature at the age of 3.0 years, attains its maximum growth rate values at 3.9 years, and has a life-span of 11.8 years. Since cassiduloids are morphologically highly conservative, with a remarkable degree of morphological stasis in their body plan, estimates of individual growth and mortality of *C. mitis* may provide insights to understanding the life history of extinct ancestors.

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### Species Identification of Juvenile Starfish Found in the Stomach of the Deep-Sea Asteroid by Comparing the Skeletal System and Nucleotide Sequence

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An astropectinid starfish, *Leptychaster anomalus* Fisher 1906, was collected from Toyama Bay, Sea of Japan by trawling at a depth of ca. 300 m. We observed two juveniles individually emerging from the mouth of an adult individual in the laboratory. In addition, 937 juveniles were found in the stomach of 808 specimens of *L. anomalus*. 412 (74.2 %) of these juveniles were alive (actively moving their tube-feet). The percentage of live prospective prey (small bivalves and ophiuroids) removed from the stomach of *L. anomalus* was significantly lower than that of juvenile starfish. Morphological observations of the skeletal system revealed that juveniles consisted of two different species, *Ctenodiscus crispatus* (Retzius 1805), belonging to the family Gonioplectinidae, and *L. anomalus* (933 of the 937 juveniles [99.6 %] are the former and the remainder [0.4 %] is the latter). The nucleotide sequences of 3'-terminal of 18S rDNA of the two types of juveniles and 6 sympatric starfishes support the comparative morphological study to identify the species: most juveniles found in the stomach of *L. anomalus* are in fact *C. crispatus* and only a small number are *L. anomalus*. We conclude that the stomach of adult *L. anomalus* is a habitat for its own juveniles and those of another species *C. crispatus*. This suggests a novel relationship between deep sea starfishes in the Sea of Japan.

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### Analysis of Genetic Population Structure in the Widely Distributed Tropical Sea Cucumber, *Holothuria (Halodeima) atra*

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*Holothuria atra* occurs throughout the tropical Pacific from the Western Indian Ocean to the eastern Pacific. It tends to be locally abundant throughout its range, although abundance may be affected by the extent to which it is exploited by the international food trade. *H. atra* can reproduce both sexually and asexually, a trait that it shares with only a small percentage of holothurians. We performed a population genetics analysis using 411 nucleotide bases of CO1 mitochondrial DNA from more than 500 individuals of *H. atra* sampled throughout its range. Most individuals were from Indonesia and the Hawaiian Islands. Data were analyzed to determine evidence for population structure at multiple geographic scales, such as between regions separated by long distances and well-defined biogeographic barriers, and within sub-regions that included principally the Indonesian and Hawaiian archipelagoes. Based on an analysis of molecular variance (AMOVA), most of the genetic variability (~80%) in Indonesia was explained by variation within local populations. In contrast, there was a significant genetic break between the Northwest Hawaiian Islands and the main Hawaiian Islands, even though the east-west geographic distance of this island chain is approximately two-thirds that of the Indonesian archipelago. Our results are discussed in the context of long-distance larval dispersal, physical barriers to gene flow, and reproductive strategy.

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### **Inheritance of Color Phenotype in the Sea Urchin *Lytechinus variegatus***

M. L. WISE AND D. RITTSCHOF

*Lytechinus variegatus* is a variably colored sea urchin common throughout the western Atlantic and Caribbean, from Beaufort, North Carolina to Brazil. Field sampling indicates that coloration in *L. variegatus* varies with geographic location and is more variable among individuals in some locations than in others. The color phenotype of the spines can be white, green, purple, lavender and pink and is often a combination of two or more colors. Pawson and Miller's 1982 experimental crosses of *L. variegatus* from Florida and Bermuda demonstrated a genetic link to color inheritance and in this study we expand on these experiments by creating a series of crosses involving several color morphs. Early stage juveniles (<4 mm in horizontal diameter) of all color crosses are very similar in appearance—translucent white with a central lavender band on the spines. Color change occurs when juveniles reach approximately 5 mm in horizontal diameter and continues until the adult color phenotype is evident (approximately 15 mm in diameter). Color in the F<sub>1</sub> generation is complex suggesting it is a multigene trait for both the spines and test. Experiments to create an F<sub>2</sub> generation are ongoing and may help shed light on the mode of color inheritance.

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